**Thames Tideway Tunnel**
Thames Water Utilities Limited

# Application for Development Consent

Application Reference Number: WWO10001

# Tackling London's Sewer Overflows

Doc Ref: **8.2.1**

## Summary Report (December 2006)

APFP Regulations 2009: Regulation **5(2)(q)**

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Thames Tideway Tunnel

Creating a cleaner, healthier River Thames

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# Tackling London's Sewer Overflows

## Thames Tideway Tunnel and Treatment - Option Development

## Summary Report

Thames Tideway

**December 2006**

Thames Water

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# 1 EXECUTIVE SUMMARY

## 1.1 BACKGROUND

On 27th July 2006, Ian Pearson (Minister of State for Climate Change and the Environment) wrote to Thames Water, requesting, *inter alia*, the development, assessment and costing of two principal options for tackling London's combined sewer overflows (CSOs). This work was to build on the earlier reports provided by the Thames Tideway Strategic Study (TTSS) and a review of this work by Jacobs Babtie.

The 27th July letter also referred to the improvements already planned for the Sewage Treatment Works (STWs) serving London that discharge to the tidal Thames. With the need to consider secondary treatment for additional collected flows and loads from intercepted overflows the opportunity has been taken to develop an optimum package of STW improvements, consistent with meeting the required objectives.

Recognising that the most significant overflow, from Abbey Mills Pumping Station, is located very close to the Olympic development site and within the Lee valley regeneration area, phasing sub-options were requested to investigate the possibility of an early deliverable for dealing with overflows at this location.

## 1.2 PROJECT STRUCTURE

To develop the various elements of work involved, a number of work streams were implemented, and each led by a working group. The chairs of these working groups, by liaison with Thames Water's project manager, ensured the coordination of outputs and activities. The work streams were:

- Solutions: to develop the engineering detail and costs of the various options
- Objectives, Modelling and Compliance: to review the environmental objectives adopted by TTSS, provide input and advice to the cost and benefit group, undertake modelling for the tunnel options and STW review, and to assess compliance of the options with the adopted objectives
- Costs and benefits: to assess the environmental and social costs and benefits of the various options
- Planning and environment: to consider the specific planning issues arising from the various options, and identify the environmental cost issues for input to the cost and benefit group

## 1.3 OBJECTIVES

The overarching objective for the development of these options is to meet the requirements of the Urban Wastewater Treatment Directive (UWWTD). This requires, inter alia, that wastewater should be collected and transported to receive treatment (generally secondary) before discharge. It recognises that overflows will occur, as it is not possible to construct collecting systems and treatment plants so as to treat all wastewater in every situation. It therefore requires member states to decide on measures to limit pollution from storm water overflows. In accordance with government guidance, and consistent with the stated aim of the directive, this has been translated into three practicable objectives where the aim is the avoidance of adverse environmental impact of urban waste water discharges on the tidal Thames and tidal River Lee. The objectives are:

- Protection of the ecology, expressed and assessed by reference to dissolved oxygen standards
- Reduction of the aesthetic impact of sewage solids and litter
- Reduction of elevated health risk attributable to intermittent sewage discharges

In view of the perceived importance of the Abbey Mills discharge, a secondary objective (for this site only) was to identify if any options permitted the practicable cessation of discharges at this location.

## 1.4 TUNNEL OPTIONS

Two principal tunnel options have been developed and evaluated as requested. The first option is a 30km long tunnel to intercept all unsatisfactory CSOs along the length of the tidal Thames from Hammersmith to Beckton. The second option is two tunnels comprising a West tunnel (with pump out to the existing sewer network) and a separate East tunnel. The two options have been considered as separate stand-alone solutions i.e. the East/West tunnel option is not designed to be compatible with conversion to the full 30 km tunnel.

Three sub-options for each of the main options have been identified for comparison. The environmental performance resulting from implementing a tunnel scheme has been assessed for each option in conjunction with the proposed Tideway STWs upgrades. All options are provided with facilities to pump out the tunnel with the appropriate additional secondary treatment necessary located at Beckton STW for the full-length tunnel and at Beckton and Crossness STWs for the East/West two tunnel solution (marginal requirement only at Crossness STW to take a proportion of the west tunnel flows).

A capital cost summary for the different options is shown below. The treatment costs (Beckton and Crossness STWs) represent the additional investment beyond that for the planned package of improvements to Tideway STWs the early phases of which are assumed within current price limits. Additional expenditure will also be required in the next few years for sludge disposal; the figures below include the apportionment of this cost that is attributable to flow collected from the tunnel options.

| Tunnel Option | Tunnels (£m) | Treatment (Beckton) (£m) | Treatment (Crossness) (£m) | Total (£m) |
|---|---|---|---|---|
| **Option 1 Full-length Tunnel** | | | | |
| Option 1a - 7.2m diameter tunnel | 1941 | 155 | 0 | 2096 |
| Option 1b - 6.0m diameter tunnel | 1874 | 147 | 0 | 2021 |
| Option 1c - 7.2m diameter tunnel (incl. Abbey Mills - Beckton direct)* | 1973 | 155 | 0 | 2128 |
| Option 1c – with early phasing of Abbey Mills to Beckton tunnel ** | 2005 | 155 | 0 | 2160 |
| **Option 2 East/West Tunnels** | | | | |
| Option 2a – West tunnel 7.6m diam, East tunnel 13m diam (Abbey Mills - Beckton) | 1538 | 97 | 27 | 1662 |
| Option 2b – West tunnel 7.6m diam, East tunnel 10m diam (Abbey Mills - Beckton) | 1471 | 187 | 27 | 1685 |
| Option 2c - West tunnel 7.6m diam, East tunnel 10m diam (Abbey Mills – Charlton - Beckton) | 1622 | 97 | 27 | 1746 |

*Additional cost for Option 1c phased takes account of extra overhead costs in undertaking the work in two stages with construction extending over an extended period.
**Cost estimate for first phase of Option 1c (Abbey Mills to Beckton tunnel and treatment) - £619m

Note:
1. All costs are at 2006 Q2 price level.
2. Treatment costs are for additional scope over that planned for upgrading Tideway STWs. These represent lowest cost conventional solutions and also include an allowance for sludge treatment costs.
3. All options incorporate the minimum treatment commensurate with pump-out of the tunnel within 48 hours after an event except Option 2b where additional treatment is required to off-set lower storage in the East tunnel
4. Options with direct tunnel link between Abbey Mills and Beckton (Options 1c, 2a and 2b) can be engineered to *eliminate* overflows at Abbey Mills with any residual spills occurring at Beckton.
5. Both Options 2a and 2b require a large diameter east end tunnel, which although technically feasible present a greater engineering and construction risk. However comparison of 2a and 2b does demonstrate that a larger tunnel capacity with less treatment (Option 2a) is more cost effective than providing additional treatment capacity to offset reduced tunnel storage (Option 2b).

## 1.5 PERFORMANCE

### 1.5.1 Environmental Objectives

It is the Tideway STW upgrades that show the largest influence on compliance with the objective set for target dissolved oxygen level in the river.

All full-length tunnel options (1a-c) are able to meet the target river quality objective for protection of ecology (all thresholds) in conjunction with the planned Tideway STW improvements when completed (assumed 2020).

For the East/West tunnel options (Options 2a-c), modelling work has shown that these options are only marginal in meeting the target river quality objective in conjunction with the Tideway STW upgrades under current climatic conditions.

In terms of achieving aesthetic improvements, the full-length tunnel options clearly perform better than the two tunnel options which do not intercept the 17 (or 16 for Option 2c) CSOs through central London. A similar result is true in terms of reducing the elevated health risk caused by discharges of untreated storm sewage. However, since there are no controls in place on sources of pathogens (primarily, but not exclusively, the treated effluent discharges to the tidal Thames), the background health risk remains, regardless of which tunnel option is considered.

Performance of the alternative options is shown below:

| | *Compliance with Objectives* | | | | | | |
|---|---|---|---|---|---|---|---|
| *Option* | *DO* | *Aesthetics (%age contribution improved)* | *Health (%age contribution improved)* | *Possible Cessation of Abbey Mills PS overflow?* | *Residual spill day events (average pa)* | *%age of unsatisfactory CSOs addressed* | *%age volume of existing overflows addressed** * |
| *1a* | *Y* | *100* | *100* | *No* | *3-4* | *100%* | *94%* |
| *1b* | *Y* | *100* | *100* | *No* | *9* | *100%* | *89%* |
| *1c* | *Y* | *100* | *100* | *Yes* | *3-4* | *100%* | *94%* |
| *2a* | *Y* | *62* | *63* | *Yes* | *As baseline ** | *53%* | *72%* |
| *2b* | *Y* | *62* | *63* | *Yes* | *As baseline ** | *53%* | *72%* |
| *2c* | *Y* | *63* | *64* | *No* | *As baseline ** | *56%* | *72%* |

*For Options 2a-2c the number of 'spill day events' will not change from the baseline due to the CSOs not intercepted. Those that are intercepted are reduced to 3-4 per year for comparability with options 1a & 1c

** All options intercept overflows from Abbey Mills which represent around 50% of the total volume of CSO overflows. However only those with direct link between Abbey Mills and Beckton can be engineered to eliminate residual spills into the River Lee.

### 1.5.2 Future Climatic Conditions

The prediction of climate change impacts is highly uncertain. However, latest (UKCIP04) scenarios suggest warmer, drier summers and warmer winters. Although it is predicted that rainfall will become 'stormier' the distribution remains uncertain and total rainfall depth may not increase greatly. Higher water temperatures are expected to impact on dissolved oxygen concentrations, both directly, by reducing the solubility of oxygen, and indirectly with biodegradation (and hence de-oxygenation) happening faster. Modelling therefore focussed on summer events, the river being less sensitive under winter conditions.

When the higher water temperatures are taken into account, the compliance position appears to change as follows:

| Option | Compliance (2006) | Compliance 2020 | Compliance 2080 |
|---|---|---|---|
| 1a | Yes | Yes | No |
| 1b | Yes | Yes | No |
| 1c | Yes | Yes | No |
| 2a | Yes | No | No |
| 2b | Yes | No | No |
| 2c | Yes | No | No |

The 2080 compliance assessment has to be seen in context in that the objectives are failed even if there were a 'perfect' solution with no overflows at all. This is because the background quality is dictated by the continuous discharges from the STWs. It is possible, if technically challenging, to restore compliance for all periods by additional treatment upgrades. The 2020 compliance assessment illustrates that due to the greater untreated loads discharged under the option 2 variants, then compensating improvements at STWs have to be either better or carried out sooner.

## 1.6 COST BENEFIT ASSESSMENT

A thorough assessment of costs and benefits has been carried out, comprising three principal activities:

- A willingness-to-pay survey, (a stated preference study) conducted both within and outside the Thames Water customer area, considering the environmental impacts described above;
- An assessment and valuation of environmental and social impacts and market benefits;
- A review of the costs of options.

These three activities were brought together as a cost benefit analysis to inform the comparison of the principal two options, and variants as appropriate.

The outcome based on preliminary cost estimates was as follows:

| | Benefits jurisdiction (All England[1] households) | | | | Administrative jurisdiction (TW customer households) | | | |
|---|---|---|---|---|---|---|---|---|
| Option | NPV (£ million) | NPV Rank | Benefit/Cost ratio | Benefit/Cost ratio rank | NPV (£ million) | NPV Rank | Benefit/Cost ratio | Benefit/Cost ratio rank |
| 1a | 2,009 | 1 | 2.04 | 1 | -423 | 1 | 0.78 | 1 |
| 1b | 14 | 4 | 1.01 | 4 | -980 | 7 | 0.47 | 4 |
| 1c[2] | 1970 | 2 | 2.00 | 2 | -463 | 2 | 0.76 | 2 |
| 1c phased[2] | 1882 | 3 | 1.92 | 3 | -550 | 3 | 0.73 | 3 |
| 2a | -447 | 5 | 0.69 | 5 | -826 | 4 | 0.42 | 5 |
| 2b | -502 | 6 | 0.66 | 6 | -881 | 5 | 0.41 | 6 |
| 2c | -516 | 7 | 0.66 | 7 | -895 | 6 | 0.40 | 7 |

*All figures in 2006 prices*
*[1]This benefits jurisdiction differs across each of the options for which willingness to pay has been estimated: for Option (1), and by implication Option 1c and Option 1c (phased), this refers to all households in England; for Option 1b this refers to all households within a 260 mile radius of the Thames, and for Option 2 refers to all households within a 170 mile radius of the Thames.*
*[2]1c does not include any Olympic related benefit estimate in this table*

The cost benefit assessment was undertaken over two different areas (jurisdictions). The benefits jurisdiction was defined to identify all of the benefits afforded by the proposed Tideway improvements (consistent with HMT Green Book guidance and the letter from the Minister). The administrative jurisdiction was defined to identify only those benefits held by Thames Water customers, the group most likely to have to pay for the improvements through their water bills. This is relevant to the consideration of the distributional consequences and how the improvements should be paid for.

For the benefits jurisdiction, three variants of option 1 (a, c and c phased) have a positive NPV and are cost beneficial. However there is little difference between them on cost benefit grounds. None of the options have a positive NPV for the administrative jurisdiction.

Under a sensitivity test which used the higher willingness to pay given by respondents to reduce the likelihood of a CSO discharge in time for the Olympics, a significantly higher NPV (£4138m) and cost benefit ratio (3.02) for option 1c (phased) was calculated than for options 1a and 1c (applied to the benefits jurisdiction). However this conclusion must be treated with an element of caution because the median WTP for this option was zero showing that if extra spending for the Olympics option had come up as a referendum, half the sample would have stated zero WTP. Further, the statistical validity of the Olympics WTP has not been explored in sufficient detail as yet because of time constraints.

## 1.7 Early phasing for 2012 Olympic Games

Previous studies have considered options to address the discharges from Abbey Mills PS, including local storage and/or treatment as well as a transfer/storage tunnel. Transfer of flows to Beckton for treatment was shown to be the only practicable option.

Option 1c offers the best opportunity out of all the options considered, for early phasing of an 'eastern' tunnel. To promote an acceptable early phase scheme it will also be necessary to provide the full additional treatment improvements at Beckton STW taking into account any sludge disposal requirements.

This early phase is compatible with a complete solution to provide the full 1c Option but will result in more frequent untreated overflows from Beckton until the second phase of full length tunnel is completed. However by undertaking an early phase significant benefits can be obtained some 7-8 years before the full scheme completion i.e. the ability to deal with overflows from Abbey Mills.

Whilst options 2a & 2b would appear comparable, the technical challenges of the larger diameter tunnels (13m and 10m respectively) compared to that of 1c (7.2m diameter) mean that these options cannot be considered viable solutions for an early phase.

The delivery of any scheme in time for the Olympics would require a very early start to be made in 2007 and suitable funding arrangements to be in place. As well as needing a fast-track construction programme it will also be dependent on achieving planning permission with the minimum of delay.

The estimated cost for the early phase of the tunnel and treatment is £619m. The phased option includes a marginal additional cost (£32m) for implementing this section of the tunnel in advance of the full scheme i.e. higher overhead costs with the phased construction extending over a longer period for the complete solution.

Although only part of a full scheme this first phase will still present a significant technical and construction challenge to complete to the set deadline. In the event of programme difficulty it may however be possible to consider early use of the tunnel for transferring flows away from Abbey Mills before all work is complete.

## 1.8 Planning

Planning approval is required before construction work can be started due to the nature and size of the development. All the tunnel options (apart from a phased option) will be subject to a fairly long planning process (potential early 'call in' and Public Inquiry) and will require purchase of land for construction and access. The best estimate has been taken for the duration of the planning process on the basis that latest planning procedures for major infrastructure projects could be implemented, although there is risk that this could prove to be optimistic.

To achieve the early phased option of 1c (direct tunnel link from Abbey Mills to Beckton together with treatment upgrade to Beckton STW) will involve the promotion of this element independent from the remainder of the full tunnel scheme, on the basis that this could be implemented at a later stage. It is considered that such an approach may permit the early phase to be dealt with solely by the local planning authority.

Agreement to proposals for extending Beckton STW to accept tunnel flows is likely to be critical. The extension and development of Beckton STW is recognised as a significant issue particularly with aspirations for regeneration in the area. Planning conditions are expected to be restrictive as a result and further work is needed to deal with these matters and any associated additional funding requirements. It will be necessary to work with other organisations, for example the London Thames Gateway Development Corporation (LTGDC) and the Greater London Authority (GLA), to identify and resolve these issues as far as possible before any planning application is made. However, this should be recognised as having potential to cause a major delay and if this cannot be resolved quickly it is highly unlikely that a solution can be in place in time for the Olympics.

## 1.9 PROGRAMME

It is estimated that the programme for the full-length tunnel options can be implemented over a 12–13 year period, provided the planning process is not unduly protracted. The programme for the East/West two tunnel options could be completed up to 12 months earlier.

An early phase for an Abbey Mills to Beckton tunnel option could potentially be available in time for the Olympics but would require a very early start in 2007, no delay with the planning process and a clear understanding of the funding arrangements. For completion of an early phase scheme in April 2012, and assuming no significant issues with construction, work on site must begin by mid 2008 at the latest. Meeting this date implies an almost immediate start on detailed design/ground investigation work with submission of planning application towards the end of 2007, and a target date for planning permission to be granted by April 2008.

The programmes for the Tideway Tunnel schemes have incorporated construction input from contractors experienced in tunnelling. The programmes are believed to be realistic but need to be considered in the context of potential construction risks with a project of this size and complexity.

## 1.10 CONSTRUCTION RISKS

All of the Tideway Tunnel options must be considered as very major construction projects. The work is unique in terms of its size, complexity and technical challenges. Although the construction methods proposed are in the main tried and tested, it is the scale of the activities to be undertaken that sets this project apart with some aspects of the engineering at the boundaries of what is technically achievable using conventional construction techniques. On top of this are the logistics of implementing the work within confined areas available for construction and a congested urban environment.

These aspects have been covered as far as it is possible at this stage of the project development with a full risk review undertaken based on outline design work for the alternative tunnel options. These risks have then been costed using the best information available.

## 1.11 TIDEWAY SEWAGE TREATMENT WORKS (STW) UPGRADES

The TTSS assumed a tunnel terminus at Crossness STW, with a high-rate primary treatment plant. The clearer requirement for full (secondary) treatment to comply with UWWTD prompted a review of this decision. Terminating the tunnel at Beckton, whilst raising planning issues, is preferable for a number of reasons, the main ones being:

- The tunnel is shorter compared with taking flow to Crossness

- It provides a better balance of treatment between the major treatment sites
- Beckton is the largest Tideway STW therefore it is best able to take the tunnel flows without the risk that this will affect treatment performance
- The majority of CSO flows are associated with the Beckton catchment
- It allows full use of the existing infrastructure i.e. Northern outfall sewer
- It aligns with the minimum tunnel solution for an early phased implementation

Considering all factors treatment of tunnel flows at Beckton STW has been assessed as the best option.

A review of the other approved Tideway STW upgrade work has been an integral part of the development work as the combined tunnel/STW upgrades need to be assessed together to determine the impact on the river and ensure the total package of work can deliver the required benefits. The first phase of remodelling indicated that the current 'work package' for the Tideway STWs was not optimal in meeting the objectives and so a review has resulted in a better-balanced set of proposals for the Tideway STW upgrades that, it is believed, can be implemented within the current envelope of cost estimates (i.e. comparable to the estimates made for the 2004 periodic review). This review was undertaken in conjunction with the Environment Agency but requires sign off on both sides and Ofwat to endorse changes and allow work to proceed in accordance with the revised proposals. Any revised delivery dates will have to be agreed taking account of the time taken to undertake this review and the changes in work now proposed.

The requirement to meet a 2021 planning horizon (rather than previous 2016), is considered appropriate in the context of the completion dates and the request to take account of expected population forecasts.

## 1.12 Funding and Finance

A specialist study has been commissioned to look into how large capital projects should be funded. The study has examined whether the current regulatory regime can deal appropriately with such projects and whether alternative approaches or delivery structures can better allocate risk and ensure that both Thames Water and Ofwat can continue to meet their legal obligations. Expert opinion has been sought to ensure that the recommended options address the concerns of the capital markets such that the desired investment is available at efficient cost when required.

It is planned to have a shortlist of options available for discussion with Ofwat in January 2007 to enable agreement to be reached on a preferred funding mechanism appropriate to the Tideway project.

## 1.13 Impact on customers' bills and affordability

### 1.13.1 Impact on customers' bills

Ofwat has calculated the possible impact on customers' bills using the conventional price-setting approach and cost figures (and profiles) provided by Thames Water. (NB. The figures supplied have since been further refined but the differences are not believed to be material.)

| Option | Bill Impact |
|---|---|
| Option 1a | £43 |
| Option 1b | £42 |
| Option 1c | £45 |
| Option 2a | £33 |
| Option 2b | £32 |
| Option 2c | £35 |

### 1.13.2 Affordability

The above price increases represent, for the option 1 variants, an uplift of some 16% on the total average bill, and perhaps 42% on the sewerage component. They will be a smaller percentage increase when compared to the likely 2020 bill which is expected to show substantial increases without an allowance for any tunnel.

The expected increases by 2020 add difficulty to the affordability assessments, although it is obvious that the number of households in 'water poverty' – defined as 3% of household income – will clearly rise, all other things being equal.

## 1.14 CONCLUSION

The Option 1 variants achieve a higher proportion of the objectives, and score more highly in the cost-benefit ranking with options 1a and 1c being broadly equal until early delivery is considered, when 1c (phased) emerges as the only variant potentially able to be delivered by 2012. All option 2 variants are characterised by a low Willingness-To-Pay and a negative NPV. Option 1c also offers a more certain route for the eastern tunnel in terms of the ground conditions at the cost of a slightly longer tunnel compared with other Option 1 variants.

Within any of the options, only Option 1c realistically offers any potential for an early phased delivery to address the Abbey Mills discharge in time for the 2012 Olympics. The additional technical challenges posed by the larger diameter tunnels (options 2a & 2b) mean that these are not considered to be viable solutions for delivery by this time.

All options for a Tideway Tunnel present a very substantial construction project with significant design and construction challenges. This needs to be taken into account in deciding which option should be selected. Although reviewed by tunnelling experts all options carry a degree of construction risk that can only be reduced by further investigation and detailed planning. The larger Option 2 tunnels carry a greater risk due to the greater technical complexity involved with tunnelling on this scale and potential effects of this work. For this reason the larger tunnel options represented by Option 2 are not preferred.

If the decision is made to implement 1c, then aside from construction risks, the following issues will need resolution:

- Early decisions and commitment by all key stakeholders to progress matters
- Planning approval
- Funding arrangements

# 2 INTRODUCTION

In the letter to Thames Water dated 27th July 2006, Ian Pearson, the Minister of State for Climate Change & Environment, asked Thames Water to lead and deliver a detailed assessment and costing of two options designed to deal with London's sewage overflows and improve sewage treatment systems. This is to be considered in conjunction with work already approved for uprating Tideway STWs.

The objective of this phase of work has been to develop proposals for measures to limit pollution of the tidal Thames by sewer overflows. Two main alternative storage tunnel options designed to collect discharges from London's major combined sewer overflows (CSOs) and transfer the flows for treatment were considered in order to meet the requirements of the UWWTD and river quality objectives. The aim has been to develop options that provide an integrated solution for meeting this objective and provide the necessary information on scope, cost, programme and benefits to enable a decision to be made on a preferred solution.

The development work has built on the work previously carried out for the tunnel proposals as part of the Thames Tideway Strategic Study (TTSS) and has been considered in conjunction with work already approved for uprating Tideway STWs.

Working Groups were set up to deal with particular aspects of the Tideway development. This has ensured that all the projects and proposals for the Tideway are developed as an integrated and complete solution.

The main working groups have therefore covered *Objectives, Modelling & Compliance, Solutions, Planning & Environment and Cost Benefit.* There has been a separate piece of work to consider funding and finance.

The ***Objectives, Modelling and Compliance Group*** has provided the necessary clarification on project objectives and the design criteria to enable the Solutions Group to work on the development of options. This has included considering the requirements and implications of existing and future legislation such as the UWWTD and Water Framework Directive (WFD). The group has also reviewed the Tideway Tunnel and the necessary upgrades to the Tideway STWs to meet CSO spill impact criterion and target Dissolved Oxygen levels in the river. This has been supported by catchment and river quality modelling.

Composition: Thames Water, Environment Agency, Defra, Ofwat, Consumer Council for Water (CCWater).

The ***Solutions Group*** has been responsible for developing selected options to meet the agreed objectives and design criteria developed for the Tideway. The work has represented a major part of the overall development work.

Early work was carried out to clarify the design criteria and develop a short-list of sub-options that met the requirements of the brief in the Minister's letter to Thames Water.

The development work has provided scoped and costed solutions with outline programmes for implementation. Working closely with the Planning and Environment group this has included an assessment of the likely planning and environmental impacts.

The options have been tested for compliance with objectives through catchment and river quality modelling.

A wide range of technical studies was commissioned employing expert and specialist input to develop the scope, cost estimates, implementation programmes and construction methodology together with an assessment of the geotechnical issues and exploratory boreholes as preliminary site investigation. The studies also included development of the tunnel operation with regard to ventilation, flushing and odour control.

Composition: Thames Water with input from key stakeholders involved in the development of solutions

The ***Planning & Environment Group*** has dealt with development of the likely planning requirements, including early consultation with organisations involved with the planning process and a preliminary assessment of likely environmental impacts. The planning strategy likely to be appropriate to the proposed development has also been investigated. The group has also worked closely with the *Solutions Group* and has guided the environmental and planning assessment of the options to ensure the results of these assessments are adequately taken into account.

Composition: Thames Water, Greater London Authority (GLA), London Thames Gateway Development Corporation (LTGDC), LB Newham, Government Office for London (GOL), Port of London Authority (PoLA), Environment Agency

The ***Cost Benefit Group*** has been responsible for assessing the proposed solutions using cost benefit techniques to confirm which will give the most favourable return taking all factors into account. The group has also reviewed previous work carried out, including the 'willingness to pay' study, and undertaken further survey work to update and provide additional robustness to the previous analysis.

Composition: Thames Water, CCWater, Defra, Ofwat, Environment Agency

The scope of the development work carried out has been in line with the requirement set out in the Minister's letter and can be summarised as follows:

> **Option 1: A tunnel to intercept intermittent discharges from unsatisfactory overflows along the length of the tidal Thames and convey the wastewater for treatment in East London. Sub-options of a 7.2m and 6.0m tunnel to be considered.**
>
> **Option 2: Two shorter tunnels, to the east and west of London, to intercept intermittent discharges along these stretches of the river, and with treatment in East London.**

Scope Definition – Following definition of the required outputs and design criteria, a short list of sub-options was developed and reviewed resulting in three sub options being agreed for both Option 1 and Option 2.

**Treatment of Pump-out Flows** – It was agreed at an early stage that collected wastewater from the tunnel should receive secondary treatment to the standards agreed with the EA as required to meet river quality objectives. The location of treatment was determined taking various factors into account and confirmed as part of this development work.

**Planned AMP4/5 Upgrade of Tideway STWs** – Option development has taken account of the planned upgrades of Tideway STWs already approved with the opportunity taken to review the treatment capacity needed to meet the needs of the environmental objectives. This has formed part of an integrated solution for the Tideway that best meets the requirements of the UWWTD.

**Cost of Options** – The main options and variations have been fully costed. A risk assessment was also undertaken and risk items costed. The costing information has also allowed the impact on customer bills to be evaluated by Ofwat.

**Early Phasing Options for Olympics** – Sub-options have been considered for early phasing of work and to assess whether measures can be in place in time for 2012 Olympics. These sub-options include:

(i) a tunnel from Abbey Mills to Charlton
(ii) a tunnel from Abbey Mills to Beckton (direct and via Charlton)

The 'fit' with the overall plan for each of the main options has also been assessed.

**Implementation Programme** – Programmes have been developed for the delivery and full implementation of the alternative options and sub-options including the advanced planning and design work.

**Cost Benefit Analysis** – An assessment of the cost and benefits of options and variations (environmental and social) has also been carried out including an update of previous work e.g. willingness-to-pay study.

**Other Factors Considered** – The following factors have also been considered during the development work as far as it is possible:

(i) Affordability
(ii) Requirements of the Water Framework Directive
(iii) Climate Change
(iv) East London Regeneration
(v) Forecast development e.g. growth in catchment
(vi) Flexibility and robustness of options for meeting future needs

**Issues & Risks** – Issues and risks associated with alternative options have been assessed including planning, environmental, engineering and cost estimates for construction and operation. Other specific issues and risks have been reviewed from work previously carried out and any additional items that are identified through the development work also be included. Odour has been looked at as a particular risk item.

**Sustainability** – Issues such as energy use and renewable energy have been considered.

**Planning, Environmental & Land** – Options have considered the implications for planning and environmental impact together with any land requirements. Initial consultation with planning authorities and other key stakeholders has been carried out.

**Funding** – Preliminary work has been undertaken to review alternative funding options taking account of the size and unique nature of this major project.

# 3 OBJECTIVES

## 3.1 INTRODUCTION

The instruction to Thames Water of 27th July did not request that new environmental objectives were developed beyond those established by the 2005 Thames Tideway Strategic Study (TTSS). Nonetheless it was clear that if the instruction was to be fully followed, a review of these objectives would be necessary for three principal reasons:

- Guidance to the engineering design teams;
- Resolving any discrepancy between TTSS and the Jacobs Babtie review;
- Providing clear outcomes (benefits) for use in the stated preference survey.

To assist in this review, the objectives group enlisted the services of Professor David Kay (Microbiology/health) and Dr Andrew Turnpenny (fisheries). Additional information and assistance was provided by Chris Lane (Health Protection Agency) and Jon Averns (Corporation of London).

## 3.2 URBAN WASTEWATER TREATMENT DIRECTIVE

The Urban Wastewater Treatment Directive, as implemented in the UK by the 1994 UWWT Regulations and subsequent guidance, is the only relevant and clear statutory basis for reviewing sewage discharges to the tidal Thames.

The broad objective of the Directive is to protect the environment from the adverse effects of inadequately treated wastewater discharges. The more specific requirements for collecting systems (sewers) are set out in Article 3 and Annex 1A and Footnote 1 of the Directive.

The key general points from these requirements are that:

a) urban wastewater (domestic and industrial sewage and rainwater run-off) should be collected and taken for treatment (normally secondary) before it is discharged;

b) the design, construction and maintenance of collecting systems is according to best technical knowledge not entailing excessive costs. Part of this consideration concerns the operation of overflows;

c) the Directive recognises that overflows will occur, as it is not possible to construct collecting systems and treatment plants so as to treat all wastewater in every situation. It therefore requires member states to decide on measures to limit pollution from storm water overflows.

Defra considers further measures, in order to limit pollution from overflows, are needed for the London collecting systems connected to Beckton and Crossness sewage treatment works and the works themselves. This is because it has been found that some of the overflows are discharging frequently and having an adverse effect on the environment.

However, the directive is silent as regards, for instance, the number of permissible overflows per year – that is for the Member State to consider when assessing the appropriate measures to limit pollution. Hence the effect of the potential measures on limiting pollution will be assessed in terms of achievement of the objectives (maintaining DO levels and protecting ecology/fish species, and reducing aesthetic impacts and health risks for recreational users) as set out below.

## 3.3 PROTECTION OF ECOLOGY

Ecological objectives for surface water bodies, including estuaries such as the Tideway, will in future be established according to the requirements of the Water Framework Directive (WFD), which has a default objective of 'good status', which will include a measure of 'good ecological status' (or, depending on the designation of the tideway as a heavily modified water body, 'good ecological potential'). Nonetheless, the precise standards which must be met for a water body to be at good ecological status or good ecological potential have not yet been set. Furthermore, good status might not necessarily be the objective for every water body, if for example achievement of it would involve disproportionate cost.

Currently, then, there are no statutory ecological objectives to apply.

The same position was recognised when the TTSS report was written, and since it is generally recognised that fish are the most sensitive indicator of ecological quality, the decision was taken to derive standards that are protective of relevant fish species. There are some 45 species of fish considered resident in the tidal Thames, but there is evidence of adverse impacts on species diversity and age distribution which appears to be linked with episodes of poor water quality and low dissolved oxygen concentrations. This is in addition to the higher-profile occasions of visible fish kills.

It may be inferred from this evidence that the ecology – specifically fish, both individuals and populations – is being adversely affected by low dissolved oxygen concentrations, and it is necessary to set protective standards to avoid this adverse impact. Setting standards on this basis is consistent with the aims of the WFD.

Initially derived empirically, these standards, which effectively define the acceptable range of variation of dissolved oxygen (DO) concentrations, were reinforced by a bespoke fishery study (see TTSS Objectives report and appendices). This study demonstrated that sensitive species showed significant mortality below 3mg/l and adverse behaviour below 4mg/l.

The oxygen standards were proposed as follows:

| Dissolved Oxygen (mg/l) | Return period (years) | Duration (tides) |
|---|---|---|
| 4 | 1 | 29 |
| 3 | 3 | 3 |
| 2 | 5 | 1 |
| 1.5 | 10 | 1 |
| *Note: The objectives apply to any continuous length of river >=3km. Duration means that the DO must not fall below the limit for more than the stated number of tides. A tide is a single ebb or flood. Compliance will be assessed using the network of Automatic Quality Monitoring stations (AQMS)* | | |

These standards establish a suite of conditions that are not alternatives, but complementary, and reflect combinations of intensity and exposure. For instance, if in any 1 year a concentration of less than 4mg/l was recorded for 30 tides, this would be acceptable provided that the concentration was not less than 3mg/l for more than 3 tides, or less than 2 mg/l for more than 1 tide, and so on.

As such these standards encompass both chronic and acute water quality issues, but recognise that extreme (but rare) events may still occur that cause fish kills.

The re-endorsement of these targets was not unanimous, and discussion centred on the uncertainty of the meaning of achieving a 'sustainable' fishery – could not significant fish mortalities be accommodated and acceptable within a sustainable context?

A further consideration arises from the UK DO standards proposed as supporting good status under the WFD: although expressed on a different basis, these standards appear to assume a more stringent minimum DO concentration

After discussion with the fishery expert, Dr Turnpenny, the majority view of the group was that the TTSS standards should remain as a defensible compromise.

**WFD and consequences of adopting differing standards**

After a review of the initial river model results, the view was taken that the TTSS standards should apply for the purposes of this report, rather than the proposed, and hence uncertain, WFD standards. This reflects four issues:

- That the proposed WFD standards are best suited to managing continuous discharges
- The major influence on the 'chronic' standard of 4 mg/l is the performance of the STWs, and the planned upgrading largely achieves this standard
- The choice between the two options under consideration is relatively insensitive to the choice of DO standard
- It is considered that the achievement of tighter DO standards will not be related to tunnel sizing, but is likely to be a feature of STW performance

However, to provide a more complete picture, it was agreed that the various solutions would be tested against the potential WFD DO standards, even if the solutions were not designed to achieve these standards.

In summary, the TTSS objective was adopted, in that it would assist the development of a more balanced and diverse fish ecology and better protect the more sensitive species already present:

***To limit ecological damage by complying with the DO standards specified in the table above)***

## 3.4 AESTHETIC IMPACTS

### 3.4.1 Visual

The aesthetic impact of storm sewage discharges takes several forms. There are the relatively persistent plastics and paper, and the organic faecal material, both of which may be seen floating in the river or deposited on the foreshore (although the latter may disperse fairly quickly). There is also the grey, greasy slick which accompanies any discharge. According to one survey, carried out several years ago, sewage litter – probably, in that instance, the persistent plastics etc. – represents about 10% of all litter items on the foreshore. Another estimate is that some 10,000 tonnes of sewage solids are discharged each year.

Whatever the precise quantity, there is little doubt that public complaint does arise, particularly where there are accumulations on the foreshore.

There are no specific quality standards for aesthetic pollution which are applicable to the Tideway. The implementing guidance to the UWWT regulations refers to screening as a requirement for storm overflows considered to be 'unsatisfactory' (i.e. causing significant visual or aesthetic impact). However there are caveats to this, and the earlier TTSS demonstrated that screening of individual discharges was in any case not practicable.

### 3.4.2 Odour

The group considered whether 'odour' - in this context, the odour arising from the intermittent discharges to the tideway – warranted separate identification as an objective. However, whilst there were clear instances of public complaint as regards treatment works (see other sections

of this report regarding the consequences for STW design and planning) there was little measurable evidence to suggest that the intermittent discharges gave rise to odour complaint, and indeed, if they did, what an objective might look like. The majority view was that whilst odour ought to be an issue, it was only likely to be so where there were accumulations of debris and hence other aesthetic criteria would apply – preventing the debris would avoid an odour problem. Hence this became subsumed into the aesthetic impact objective.

The objective adopted for TTSS [for visual aesthetic impacts generally], and re-endorsed here, was

***To reduce the frequency of operation and limit pollution from those discharges which cause significant aesthetic pollution, to the point where they cease to have a significant adverse effect***

As this objective is descriptive, it was necessary to derive a measure to establish the degree of reduction achieved. On behalf of the group, the Environment Agency developed a protocol which weighted the location (visibility) and size of discharges such that the various options could be tested. This protocol gives rise to the assessments in the performance table in section 1.5.1 and is described in the objective report.

## 3.5 HEALTH IMPACTS

The Thames Tideway is not designated bathing water and, as such, there are no nationally agreed microbiological quality standards to be applied.

It is recognised that an estimated 3000-5000 people per week use the tideway for recreation, mainly rowing. The health risk to these people is a combination of hazard (crudely, the presence of pathogens in the water), the mode of exposure which provides the potential route for infection (principally ingestion), the numbers of pathogens in the water, and the dose likely to cause illness. The health risk assessment which underpins the recent WHO (2003) *Guidelines for Safe Recreational Water Environments* has been carried out on, and for, bathing waters and assumes head immersion (and by implication a risk of water ingestion via the nose or mouth).

There has been some previous research on other recreational uses such as rowing, canoeing and sailing which 'may', in some cases, carry a lower risk of ingestion.

Monitoring has demonstrated that bacteriological counts of indicator organisms found in the areas of the Thames where the intensity of users is high, generally exceed World Health Organisation 'recommended' levels for bathing, even under dry conditions. This is almost certainly due to the large volume (and proportion) of treated, but not disinfected, sewage effluent present in the Tideway. Based on research carried out at the National Water Sports Centre at Holme Pierrepoint, the 'background' (i.e. without intermittent discharge impacts) conditions are such that there is a high risk of infection if immersion occurs.

Routine bacteriological monitoring shows that under wet weather conditions, (i.e. when the intermittent discharges may be expected to have operated) the concentration of indicator organisms is increased by perhaps 20 fold. Whilst there is no agreed relationship, illness risk rates could be expected to be 'very high' (i.e. exceed those predicted under background conditions). Nonetheless, this gives no indication to any changed risk for any group of activities which have no risk of immersion in water.

The Corporation of London commissioned the Health Protection Agency (HPA) to conduct a health questionnaire survey of rowers using the tideway. This has yet to report, and the survey structure may preclude a robust statistical comparison between this group and members of the general public, but it appears that most of the illnesses reported were associated with immersion and hence are broadly consistent with literature findings.

The HPA study reinforces the view that any water-based activities on the Tideway that involve a risk of immersion and/or ingestion will result in a high risk to the health of those so exposed. One significant contribution has been to identify the fact that indicator organisms in the tideway remain elevated for between 3 and 5 days after a discharge event.

The TTSS adopted a concept of 'elevated health risk days', which sought to link the elevated (but unspecified) health risk to a frequency of discharge (60 times per year) and a die-off period of 2 days. This simple calculation gave 120 days of elevated health risk.

It is now clear that the baseline health risk in periods of dry weather, (i.e. without intermittent discharge contribution) is already high, but although the risk of infection is elevated under wet conditions, it is not possible to quantify this increased risk, even following immersion, However the interim results of the study suggest that this increased hazard may persist for longer than previously assumed.

It is not possible to empirically identify the risk to recreational users, be they participating in rowing or other activities with a different immersion risk. Nonetheless, there is sufficient evidence to suggest that the risk to users of the Tideway is generally high and will be greater following intermittent discharges.

In this instance a different objective to the TTSS was adopted, as follows:

***To help protect river users by substantially reducing the elevated health risk due to intermittent sewage discharges.***

As with aesthetic considerations, this is a descriptive objective and again the Agency developed a protocol, based on the location and size of discharge to weight the impacts of the various intermittent discharges. This assessment is reported in section 1.5 and the detailed protocol is to be found in the objectives group report.

## 3.6 SEWER FLOODING

It is assumed that the provision of a tunnel connection will allow the free discharge of gravity overflows into the tunnel at any state of tide; this should, in theory, manifest as a reduced flooding risk for a number of properties. Although this would be best tested by comprehensive modelling, in the time available a desk exercise was carried out, which, based on the elevation of drained areas, suggested the benefit was actually quite small – perhaps a reduced risk for some 150 properties for the full-length tunnel options, and perhaps 100 properties for the East/West two tunnel options. On this basis it does not seem to be a specific objective to differentiate between options, although it should be reflected in the benefits assessment.

# 4 DEVELOPMENT OF OPTIONS

The two main Tideway Tunnel options, each with three variants, are developments of the Thames Tideway Strategic Study (TTSS) recommended option, which included a storage tunnel with pump-out to a dedicated storm treatment plant.

Following the request to review selected options for a tideway tunnel, it was agreed at an early stage of the development work that collected wastewater should receive secondary treatment to the standards required to meet river quality objectives for dissolved oxygen (DO). The location of treatment has been determined taking various factors into account and confirmed as part of this development work.

The principle modification to the previous storage tunnel concept is the proposal to terminate the full-length and eastern tunnels at Beckton Sewage Treatment Works (STW) for pump-out to full treatment.

In conjunction with the treatment requirements for the tunnel, the option development has also encompassed a review of the planned upgrades of Tideway STWs that have already been approved for commencement in AMP4. Options have been assessed to re-balance treatment capacity to meet the needs of the tunnel and environmental objectives. This has formed part of an integrated solution for the Tideway that is considered to best meet the requirements of the UWWTD.

A wide range of technical studies was commissioned to report on the various elements of the options, such as scope, cost, programme, operation etc. These studies are summarised within this report and their findings incorporated to develop and assess the two main options.

## 4.1 OPTION OVERVIEW

### 4.1.1 Options

The two principal options, each with three variants are detailed below together with the required Flow to Full Treatment (FFT) capacity in Mega litres per day (Mld), are listed in the table below:

| Option | Description of Tunnel Element | FFT at Beckton STW (Mld) |
|---|---|---|
| 1a | Full-length Storage Tunnel – 7.2m Diameter | 2,336 |
| 1b | Full-length Storage Tunnel – 6.0m Diameter | 2,105 |
| 1c | Full-length Storage Tunnel – 7.2m Diameter, tunnels joining at Beckton | 2,336 |
| 2a | West Tunnel, 7.6m Diameter & East Tunnel, 13m Diameter | 1,912 |
| 2b | West Tunnel, 7.6m Diameter & East Tunnel, 10m Diameter, with Supplementary Additional Treatment Capacity | 2,700 |
| 2c | West Tunnel, 7.6m Diameter & East Tunnel (via Charlton), 10m Diameter | 1,912 |

The required FFT for each option is based on the sum of the average maximum draindown rate from the tunnel and the average flow to the Beckton STW projected to 2021. The exception is Option 2b, the east tunnel of which has a smaller volume than Option 2a. Therefore 2b incorporates supplementary additional treatment capacity to facilitate greater transfer of flow direct to the works during an event.

Implementation of an early phase of each option and its variant has been investigated for the implementation of an eastern tunnel that could be utilised to transfer or reduce Abbey Mills PS CSO discharges.

These include the following possible options:

| Option | Description of Tunnel Element |
|---|---|
| 1a | 1. Abbey Mills to Charlton– 7.2m Diameter<br>2. Abbey Mills to Beckton via Charlton – 7.2m diameter |
| 1b | 1. Abbey Mills to Charlton– 6.0m Diameter<br>2. Abbey Mills to Beckton via Charlton – 6.0m diameter |
| 1c | 1. Abbey Mills to Beckton – 7.2m Diameter |
| 2a | 1. Abbey Mills to Beckton - 13m Diameter |
| 2b | 1. Abbey Mills to Beckton - 10m Diameter |
| 2c | 1. Abbey Mills to Charlton– 10m Diameter<br>2. Abbey Mills to Beckton via Charlton – 10m diameter |

Of note is that CCWater raised a further option for a full tunnel option at a late stage in the development process. This would be a variation on Option 1c but with a direct connection between the North Eastern Storm Relief shaft and Abbey Mills PS thus reducing the length of the main 'spine' tunnel. However to achieve equivalent performance would require long connection tunnels to pick up CSOs that would otherwise be bypassed and increased tunnel size to provide the necessary storage volume. Another disadvantage is that it would not provide a configuration that could eliminate spills at Abbey Mills.

### 4.1.2 Design and Performance Criteria

The design of the tunnels is based on providing the necessary storage capacity to capture overflows from identified CSOs to ensure spills from each of those overflows to river do not exceed a target of an average of around three spill day events per year. This is for the full-length (7.2 m diameter) tunnel solution. The performance of other options and variants will be proportionately less with the reduced storage of the alternative full tunnel (6 m diameter) and fewer CSOs intercepted by the East/West two tunnel solutions. The exact performance has been confirmed by catchment modelling.

The overall Tideway scheme (tunnel in conjunction with upgrades to the Tideway Sewage Treatment Works) is designed to meet target river quality objectives in terms of set dissolved oxygen levels. This has been confirmed through river quality modelling.

### 4.1.3 Main tunnel shafts

The location of the main shafts is an important factor in establishing the route and developing the design of the tunnel. These shafts will be key to the construction of the tunnel and subsequently access for maintenance. Unfortunately not all shafts can be located on land owned by Thames Water and will therefore require acquisition of land. This means the final proposals cannot be confirmed until these sites are secured.

Potential construction and operational challenges have been identified with the western most shaft located on the river foreshore (near Hammersmith). Further work is necessary to see if these difficulties can be overcome. However at this stage one of the previously assessed alternative sites is now being considered as the preferred location. Tunnel routes have been modified slightly to suit.

### 4.1.4 Tunnel draindown and pump-out

The maximum pump-out capacity for emptying the tunnel for each option/variant is based on draining the tunnel storage volume in 48 hours. This ensures the tunnel is emptied in

sufficient time to provide storage for the next event and this has been taken into account in modelling the proposed solutions. This pump-out rate also determines the treatment requirement. Retaining flow in the tunnel for any longer would also risk septicity and potential issues with treatment and odour.

Not all events will completely fill the tunnel, therefore there will be potential opportunities to consider alternative modes of operating for rate of drain-down e.g. to reduce energy costs, smooth flow to treatment, make maximum use of available storage and treatment capacity. Determining the optimum operating regime will require more detailed evaluation. However the outline design at this stage of development provides the necessary flexibility for this to be considered.

#### 4.1.5 Treatment considerations

The tunnel terminates at Beckton for full treatment of tunnel pump-out flows. This saves the extra length of tunnel and an additional shaft necessary for the tunnel to continue on to Crossness. The storage capacity of the tunnel has been maintained by adjusting the diameter of the tunnel along the Abbey Mills link. This has no effect on the connection of CSOs and the overall solution is more efficient as a result.

The treatment capacity provided at the receiving works (Beckton for the full-length tunnel options, Beckton and Crossness for the East/West tunnel options) will allow for the tunnel volumes to be pumped out over a 48 hours period in the period following the storm event. Over this period the actual drain-down rate will be varied to match the available treatment capacity to take account of diurnal variation in flow to the works. It should also be possible to make use of this additional treatment capacity during an event to increase the effective volume captured before spills occur.

The facilities required at Beckton to treat the tunnel flows are based on an extension to the existing works and would be complimentary to the extensions already proposed to uprate the treatment capacity as part of the overall Tideway scheme. These facilities will require planning permission but if as part of wider consideration, alternatives are sought (e.g. as part of plans for regeneration of the area), this could delay implementation and/or require additional investment.

#### 4.1.6 Spills at Abbey Mills Pumping Station

The options that provide a direct connection between Abbey Mills and Beckton (Options 1c, 2a and 2b) can be engineered with the capability to eliminate overflows at Abbey Mills. Although it is not a specific objective to eliminate spills, in this configuration any residual spills are transferred to the River Thames at Beckton rather than into the smaller flows of the River Lee, and the potential environmental impact will be reduced.

#### 4.1.7 Phased delivery

Options for phased delivery of part or all of the eastern section of the tunnel have been assessed. These options all centre on early delivery of facilities to intercept overflows at Abbey Mills and pump flow either via Charlton or direct to Beckton in conjunction with (limited) storage offered by the first phase of the tunnel. These options make use of the existing pumps at Abbey Mills to drive the flow through the tunnel, then out of the receiving shaft to a purpose built outfall with facilities to discharge direct to the river. The connection to Beckton provides the opportunity to reduce this discharge to the river provided treatment upgrades are in place.

This must be considered as an interim phase of a full solution with in some cases the limited storage capacity available to provide adequate performance on its own. The hydraulic characteristic of the connecting tunnel is a significant factor in the performance of this early phase of work to reduce or eliminate spills at Abbey Mills. It should be noted that the options with a direct link between Abbey Mills and Beckton offer the opportunity of eliminating overflows at Abbey Mills by utilising a pumped connection and transferring residual spills to Beckton.

The pump-out facilities at the receiving shaft will be for drain-down purposes at the end of an event. The alternative of a full pump installation at the receiving shaft to discharge the full flow is not considered a viable alternative due to the size and cost of the infrastructure required and the fact it would become redundant with the implementation of the full solution.

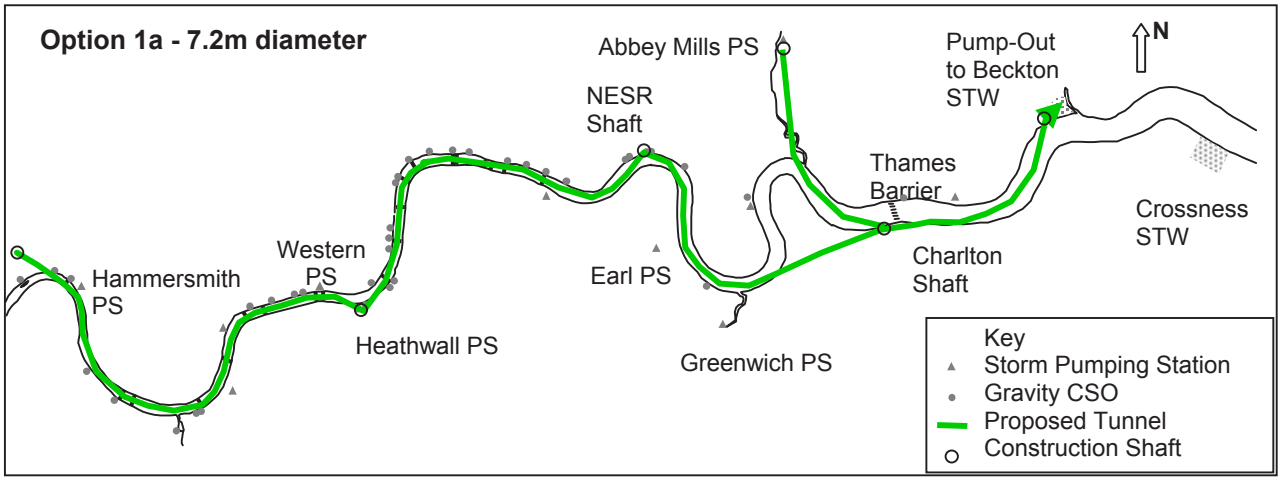
The implementation of any phased option will be dependent on gaining early planning permissions for the proposed works. This is a key factor in determining the programme for early delivery.

4.1.8 Small Scale Measures

For the East/West two tunnel options, it may be possible to partially mitigate the effects of not intercepting the CSOs in the middle section of the Tidal Thames by continued use of the 'Bubblers' (oxygen injection) and deployment of the new litter collection vessels. It is considered unlikely that these small-scale measures can achieve the same performance as intercepting the flows however it is difficult to assess the comparative benefits in advance of the vessels being deployed.

## 4.2 Option Details

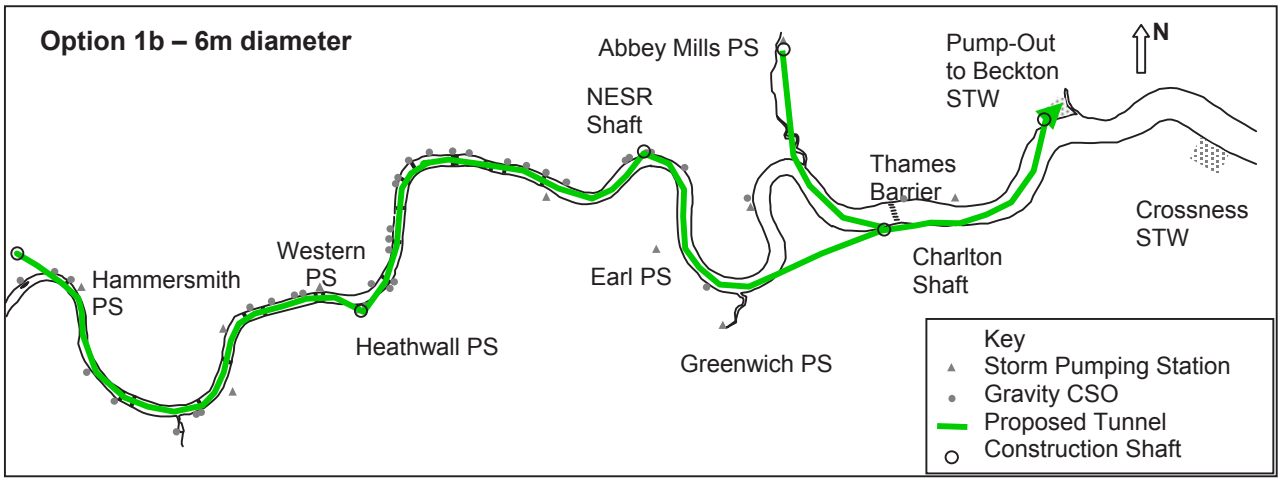
### 4.2.1 Option 1a: Full Storage Tunnel – 7.2m Diameter




**Scope**

Main Tunnel: 32.2km @ 7.2m diameter tunnel
Abbey Mills Link: 5km @ 7.2m diameter
Construction shafts: 5
Pump-Out Shafts: 1
CSOs Intercepted: 36
Total Storage Volume: 1, 618,000 $m^3$
Pump-out to Beckton only.

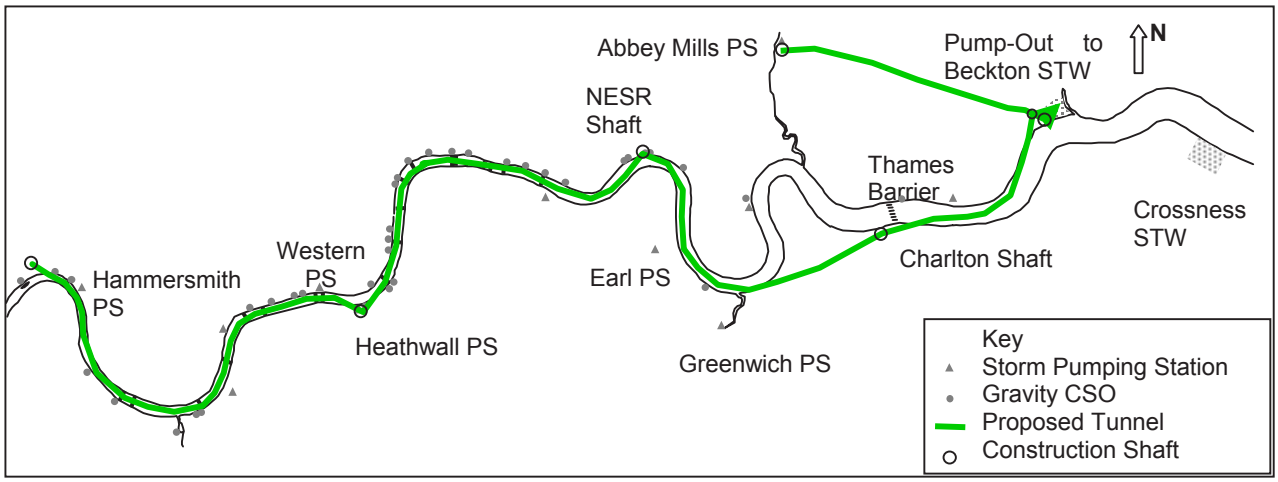
4.2.2 Option 1b: Full Storage Tunnel – 6.0m Diameter




**Scope**

Main Tunnel: 32.2km @ 6.0m diameter tunnel
Abbey Mills Link: 5km 6.0m diameter
Construction shafts: 5
Pump-Out Shafts: 1
CSOs Intercepted: 36
Total Storage Volume: 1,155,000m$^3$
Pump-out to Beckton only.

**4.2.3** Option 1c: Full Storage Tunnel – 7.2m Diameter – Tunnels Join at Beckton

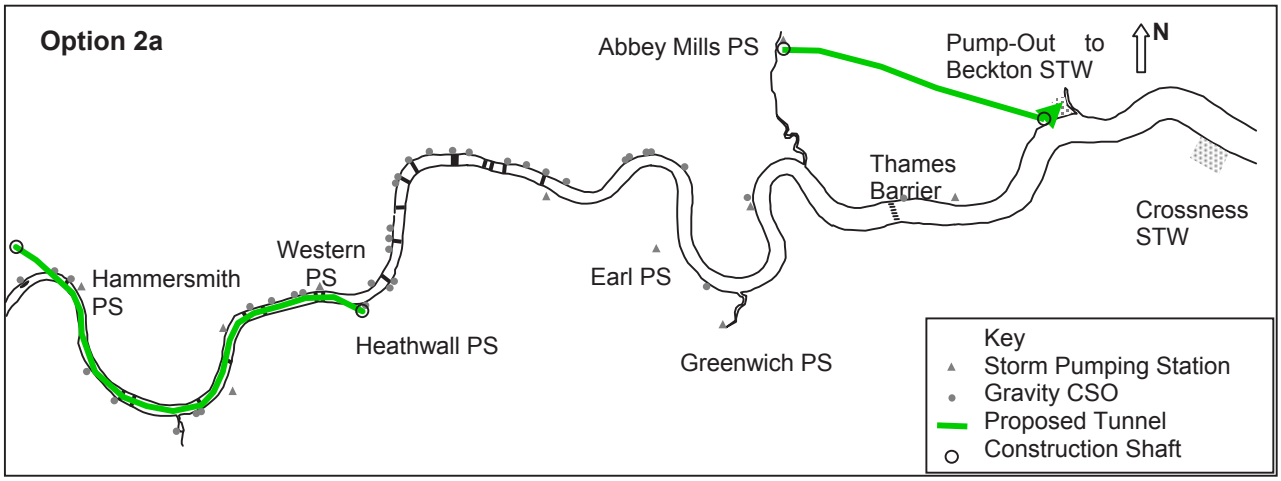



**Scope**

Main Tunnel: 32.2km @ 7.2m diameter tunnel
Abbey Mills Link: 5.5km @ 7.2m diameter
Construction shafts: 5
Pump-Out Shafts: 1
CSOs Intercepted: 36

Total Storage Volume: 1,638,000m$^3$
Pump-out to Beckton only

4.2.4 Option 2a: West Tunnel 7.6m Diameter & East Tunnel 13m Diameter

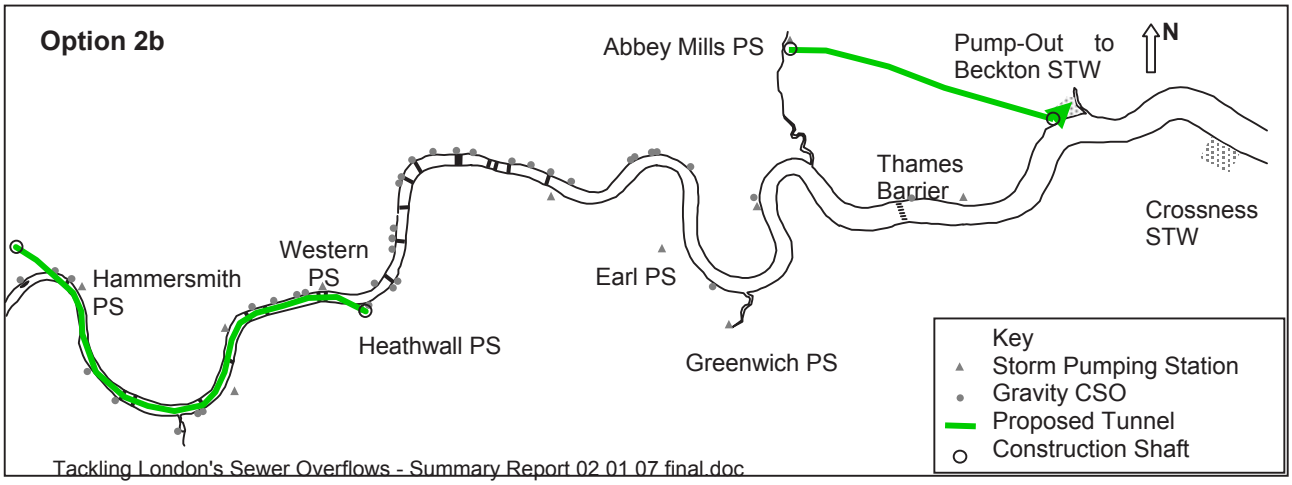



**Scope**

East Tunnel:
Abbey Mills to Beckton 5.7km @ 13.0m diameter tunnel;
Approximate volume 769,000m$^3$
Construction shafts: 1
Pump-Out Shafts: 1; to Beckton only
Abbey Mills only intercepted
Pump-out to Beckton only.

West Tunnel:
Homefield to Heathwall; 10.7km @ 7.6m; Volume 492,000m$^3$.
Construction shafts: 1
Pump-Out Shafts: 1; return to system
Link tunnel to north of river
CSOs Intercepted: 17
Pump-out at Heathwall to the "spare" capacity afforded by the low level north and south interceptor sewers and additional treatment capacity at Beckton and Crossness.

4.2.5 Option 2b: West Tunnel 7.6m Diameter & East Tunnel 10m Diameter, with Additional Treatment Capacity

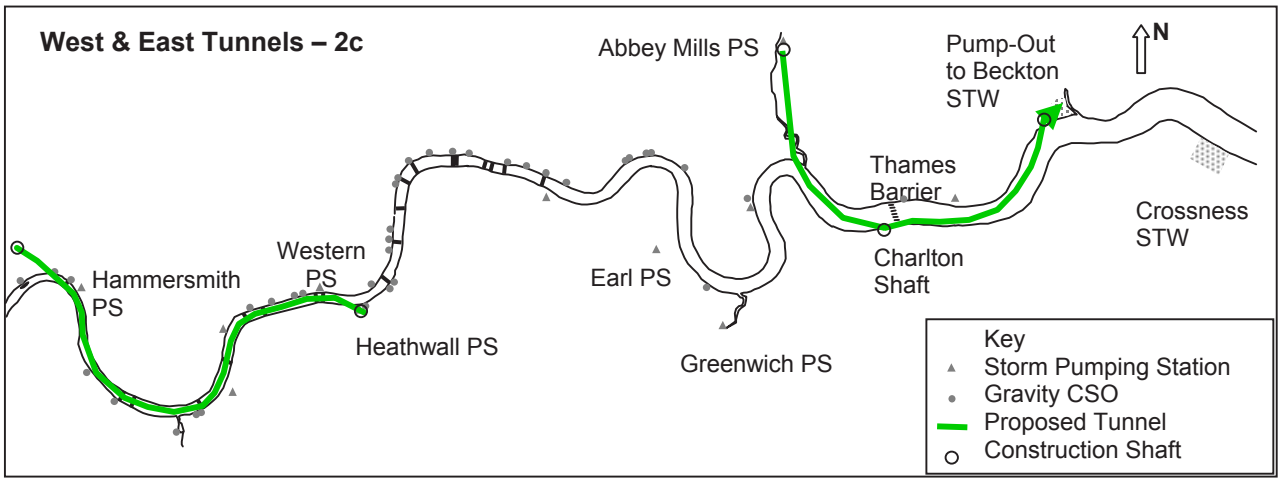


**Scope**

East Tunnel:
Abbey Mills to Beckton 5.7km @ 10.0m diameter tunnel;
Approximate volume 455,000m$^3$
Construction shafts: 1
Pump-Out Shafts: 1; to Beckton only
Abbey Mills only intercepted
To maintain bypass performance with the smaller (10m diameter) tunnel, flow to full treatment at Beckton needs to be increased significantly so that additional flow can be treated during a storm event.

West Tunnel - As Option 2a

4.2.6 Option 2c: West Tunnel 7.6m Diameter & East Tunnel (via Charlton) 10m Diameter




**Scope**

East Tunnel:
Abbey Mills to Charlton 5.0km @ 10.0m diameter
Charlton to Beckton 4.0km @ 10.0m diameter
Construction shafts: 2
Pump-Out Shafts: 1 – Beckton only
Volume 769,000m$^3$, equivalent to East Tunnel of Option 2a
Abbey Mills and Charlton only intercepted;
Pump-out to Beckton only.

West Tunnel - As Option 2a

4.2.7 Treatment of Tunnel Flows

From a technical point of view development work has confirmed that treatment capacity for tunnel pump-out is better located at Beckton.

It allows a better balance of treatment capability between Beckton and Crossness taking account of the upgrades required at both works to meet river quality objectives.

Additionally, if tunnel pump-out was provided at Crossness the proportional increase in hydraulic load would be significantly greater, raising concerns on the impact on the treatment process during pump-out events.

Most of the flow that will be collected from the CSOs is from the Beckton catchment, with half of the total flow coming from Abbey Mills, which is the terminal pumping station for Beckton STW.

Optimum use of the existing infrastructure would also be compromised (e.g. use of the existing Northern Outfall Sewer), if treatment were at Crossness.

As compared to a tunnel which terminated at Crossness, construction of facilities for tunnel drain-down and treatment at Beckton will save the considerable cost associated with approximately 4.1 km of 7.2 m diameter tunnel and a shaft at Crossness, plus the cost of the 1.35 km of 3 m diameter branch tunnel required to connect Beckton STW to the main tunnel.

Construction of treatment facilities at Beckton aligns with the minimum tunnel solution for early phased implementation.

The tunnel falls at a constant gradient and hence there would be a slightly higher energy cost associated with a drain-down pumping facility at Crossness as compared to Beckton.

## 4.3 Option Assessment

### 4.3.1 Technical Issues

Any option of the Tideway Tunnel represents a very major construction project. It is exceptional though not entirely unique in terms of its size, complexity and technical challenges. Although the construction methods proposed are in the main tried and tested, it is the scale of the activities to be undertaken that sets this project apart with some aspects of the engineering at the boundaries of what is technically achievable using conventional construction techniques. On top of this is the logistical challenge of implementing the work within confined areas available for construction and a congested urban environment.

These aspects have been covered as far as it is possible at this stage of the project development with a full risk review undertaken based on outline design work for the alternative tunnel options. These risks have then been costed using the best information available.

As all the options incorporate the construction of large tunnels, deep shafts, and the interception works for the CSOs, many of the risks are common. In general the construction risks can be managed by invoking adequate strategic site investigation works and employing best construction practice. The main differentiating risks and issues between the options are detailed below:

- All the main options (except early phase between Abbey Mills and Beckton) require land acquisition for at least some of the shaft sites. Should the identified sites become unavailable or acquisition delayed, then additional cost and delay will be incurred for procurement of alternative sites, redesign of significant elements and less efficient construction.

- The west tunnel of Options 2a–2c is isolated from the treatment facilities that are located in the east of the catchment. Therefore intercepted flow can only be pumped out to the intercepting sewers after flows have returned to normal, and there is spare capacity in existing sewers to allow for these additional flows. Careful control of the pump-out regime would be required to ensure that downstream flooding or overflow to the river does not occur. The average flow in the interceptor sewers will obviously increase during this period of pump-out and should another event occur there is a risk that the volume of discharge will be greater from the un-connected CSOs. This

increase in average flows in the interceptor sewers effectively reduces spare capacity that would otherwise be available to service future development.

- The tunnel route between Abbey Mills and Charlton generally follows the Lee Valley. The geology here is significantly faulted and disturbed and therefore more variable and unpredictable. This aspect will increase construction risk for Options 1a, 1b and 2c. However the geology for the route directly between Abbey Mills and Beckton (Options 1c, 2a and 2b) is more predictable and therefore the risk reduced.

- Generally the geology for the tunnel routes following the River Thames is reasonably well understood and therefore more predictable. However there will be zones, where variability is much greater. In particular this would impact on the CSO shafts and interconnecting tunnels in the central section, therefore the implementation of specialist geotechnical works, has been included in the scope and budget estimates. The precise nature of such works would be determined following a detailed ground investigation work.

- Launching tunnelling machines for the 10m and 13m diameter east tunnel of Options 2a–2c, from the shafts would require the construction of significant underground chambers to facilitate assembly of tunnelling machinery and therefore incur significantly more risk. There is little experience of these activities as such large tunnels are normally associated with transportation projects and therefore driven from portal structures close to ground level. Conversely machinery for the 6m and 7.2m diameter tunnels for Options 1a, 1b and 1c could be launched through portals in the shaft walls thus maintaining ground support during this operation.

- The tunnel route between Abbey Mills and Beckton will pass under existing and currently planned infrastructure at various locations. The predicted ground settlement will be significant enough for the 13m diameter tunnel (Option 2a) to give concern and possibly be unacceptable. The potential impact from the 10m tunnels (Option 2b) will be less, but still significant. It is possible therefore that the 7.2m tunnel (Option 1c) would be the only option that can be constructed within manageable limits along this route.

#### 4.3.2 Environmental Performance

The two main tunnel options, namely the complete 7.2m diameter tunnel from Hammersmith to Beckton (option 1a), and the two-part East-West tunnel option (Option 2a) have been put through the water quality estuary model along with their variant options (Options 1b, 1c, 2b & 2c) and have been assessed against an historical set of 154 of the most significant storm events occurring over a 34 year period. Each solution has also been analysed for the frequency with which they will be beaten and hence occasional spills will occur on average per year.

Changes have been made to the modelling process since the TTS Studies reported in 2005, largely as a result of the better understanding of the various input assumptions in the model. The modelling process has also been improved to include:

- The impact of predicted population change up to 2021,
- The impact of predicted climate change up to 2020 and beyond,
- The impact of smaller rainfall events occurring in between the historical set of 154 events used to assess compliance; and
- Revised Sewage Treatment Works (STW) consent standards for the proposed Thames Tideway Quality Improvements (TTQI) STW projects currently under planning.

All the above factors have been included in the determination of compliance of the various solutions ensuring that the predicted performance of each solution is as robust as possible.

An assessment has also been made against potential compliance with the proposed UK draft Water Framework Directive (WFD) Dissolved Oxygen (DO) standards for estuaries. Whilst

these two factors have been modelled, they have not been used to differentiate the compliance of the various tunnel options and variants.

The modelling results have demonstrated a greater level of robustness as they have included changes to the modelling process which show that compliance with the DO objectives can still be met from a considerably worse baseline than was the case during the TTSS studies, including the impact of climate change up to the 2020s, population increases and the impact of smaller storm events occurring before the larger, more significant storm events are assessed. This is partly due to the more robust package of Tideway STW improvements derived from the additional development work carried out.

4.3.2.1 Interception of CSO spills

Two catchment model approaches have been used to assess the interception performance of each option. The first utilised simplified models for a data-set of 34 years and the second used full model runs for a typical year. The first method is a simplification but gives a good estimation of the average frequency of bypass. The model runs for the typical year, however, gives a better estimation of the relative volumes of interception for each option. The table below summarises the results:

| Option | Bypass Frequency (Spill Day Events) | | Typical Annual Volumes ($m^3$) | | |
|---|---|---|---|---|---|
| | Average | Typical Year | Bypass | Interception to tunnel | Interception Direct to Treatment |
| 1a | 2-4 | 1 | 1,018,582 | 35,840,388 | 11,278,619 |
| 1b | 5-9 | 3 | 2,311,479 | 37,749,623 | 8,062,263 |
| 1c | 2-4 | 1 | 993,171 | 35,977,253 | 11,278,622 |

The bypass frequency for the typical year is lower than average as there are fewer large rainfall events in this dataset. The increased interception of flow to the tunnel for Option 1b seems illogical at first. However this option incorporates lower treatment capacity at Beckton STW, therefore less flow is diverted directly to the works via Abbey Mills, as shown by the lower annual total for interception direct to treatment. Correspondingly, for most events which would have a volume less than the volume of the tunnel, more flow is passed to the tunnel for this option.

| Option | Bypass Frequency (Spill Day Events) | | Typical Annual Volumes ($m^3$) | | | |
|---|---|---|---|---|---|---|
| | Average (E/W Tunnels) | Typical Year | Bypass (connected CSOs) | Interception to tunnel | Interception Direct to Treatment | Spill from un-connected CSOs |
| 2a | 2 & 9 | 2 | 904,157 | 22,017,164 | 9,802,174 | 10,113,158 |
| 2b | 2 & 9 | 5 | 1,559,284 | 12,009,917 | 19,134,742 | 10,774,115 |
| 2c | 2 & 9 | 2 | 971,305 | 19,943,480 | 9,797,642 | 10,179,582 |

The bypass frequency for Options 2a – 2c is quoted for the *CSOs connected to the tunnel* lengths. However these options do not intercept 16/17 CSOs in the middle section of the Tidal Thames, and these CSOs would continue to discharge unimpeded. Therefore in overall terms there is no reduction in spill day events but the volume of overflow and potential adverse impact will be reduced.

The wide range in average bypass frequency for these options is due the difference of interception between the east and west tunnels.

#### 4.3.2.2 Compliance With River Quality Target (Dissolved Oxygen DO)

The output of the catchment modelling work was also used to test compliance with the Dissolved Oxygen (DO) standards developed to achieve sustainable fish populations. Only Options 1a, 1b and 1c reach compliance with the DO objectives. Options 1a and 1c, by virtue of their greater overall interception performance are more robust in achieving these standards than Option 1b. Options 2a, 2b and 2c all fail the DO objective (taking account of predicted climate change by 2020) and hence are less likely to achieve sustainable fish populations.

#### 4.3.2.3 Compliance with Water Framework Directive (WFD)

A method has been derived for the testing compliance against draft WFD DO standards. Modelling to date has shown little difference between solution performances for the WFD directive standards with all solutions deemed compliant for the intermittent discharge standard, and all solutions improving the reliance of the Tideway achieving 'moderate status'. If 2020's climate change and preceding events are included, the future baseline would result in a 'poor' categorisation for the Tideway without a CSO solution in place. Modelling for a single option (1a) showed that the Tideway would return to moderate status if a solution of this magnitude were applied.

#### 4.3.2.4 Carbon footprint

An assessment of the carbon emissions of the various options has indicated that, as may be expected, there are greater emissions both during construction and operation for the Option 1 variants than for those of Option 2. A table from the Cost Benefit work is reproduced below:

| **Issue** | **Carbon dioxide emissions (tonnes)** | | | | | |
|---|---|---|---|---|---|---|
| | **1a** | **1b** | **1c** | **2a** | **2b** | **2c** |
| Embodied energy | 590,202 | 515,968 | 601,298 | 397,232 | 327,981 | 362,665 |
| Energy for tunnel boring | 181,126 | 181,048 | 183,849 | 124,539 | 124,480 | 130,927 |
| | **Carbon dioxide emissions (tonnes per year)** | | | | | |
| Energy for tunnel pumping | 6,318 | 6,549 | 6,318 | 5,458 | 3,200 | 5,458 |
| Energy for treatment of captured sewage | 8,437* | 7,021* | 8,437* | 4,718* | 9,817* | 4,718* |
| Energy generated | < -256# | < -256# | < -256# | < -205# | < -205# | < -205# |

* These figures assume zero carbon dioxide emissions on 20% of the energy requirement

# These figures are maximum savings assuming zero carbon dioxide emissions from energy from biomass

### 4.3.3 Cost Estimates (Tunnel & Treatment)

#### 4.3.3.1 Capital Costs

The Tideway tunnel and treatment cost estimates have been derived through a process of estimating the Civil, Mechanical, Electrical and ICA elements of the project.

Civils - Quantities have been established by measurement from drawings and sketches where available, for the large parts of each process being assessed and scheduled out in a Bill of Quantities style format. These have subsequently been priced using a build up of current rates from the various elements, which form an all in rate for the various work packages. Prices have also been used from previous projects undertaken in both AMP3 and AMP4 and if necessary updated using current construction indices. Alternatively quotations have been obtained for sub-contract packages.

Mechanical - Mechanical elements have been scheduled out in a Bill of Quantities format from information supplied through the process engineering the with rates and prices having been derived from both contractor quotations, framework manufacturers prices and cost elements from previous projects updated where necessary.

Electrical and ICA - Electrical and ICA sums have been assessed using rates and prices from previous projects or contractor information. Where possible rates have been put against assumed quantities derived from drawings and sketches.

Risk allowances- A Risk Workshop was held with key team members from different disciplines to establish the likely risks for the project. These were detailed with the @Risk system along with percentage for likelihoods of occurrence, cost and time impact. Three point estimates based on figures within the project base construction and management costs were used to establish the minimum, most likely and maximum costs. These were then simulated through @Risk to provide an allowance sum for project risk.

Resource costs (detailed design, specialist consultancy) - Resource and design costs have been included by a percentage added to the base construction costs. The percentage has been derived through Thames Water's engineering estimating system, which collects costs for the various projects undertaken by Thames Water through the previous AMP periods. This information has been collated and assimilated to produce an average percentage addition for resource on cost, design and other Thames Water project costs.

The estimated cost of each option including the required increase in treatment capacity is summarised in the table below:

| Option | Estimated Capital Cost £M @ 2006 | | | |
|---|---|---|---|---|
| | Tunnel & Shaft Works | Treatment Plant | Total | (Contingency included)* |
| 1a | 1941 | 155 | 2096 | 309 |
| 1b | 1874 | 147 | 2021 | 308 |
| 1c | 1973 | 155 | 2128 | 309 |
| 1c in two phases** | 2005 | 155 | 2160 | 319 |
| | | | | |
| 2a | 1538 | 124 | 1662 | 264 |
| 2b | 1471 | 214 | 1685 | 264 |
| 2c | 1622 | 124 | 1746 | 264 |

*The above table identifies the contingency assessed for each option. The level of contingency is commensurate with the construction risks identified elsewhere in this report and reflects the uniqueness and complexity of the work involved.

**The cost of implementing the first phase of Option 1c is estimated at £619m. This includes the tunnel length (at 7.2m internal diameter) between Abbey Mills and Beckton, together with

the extension of Beckton STW to 2,336Mld, the capacity required for the complete option. This is considered to be the only early implementation option that has potential to be delivered by the Olympic period in 2012.

The total cost of completing Option 1c in two phases increases due to costs associated with remobilisation and extended overhead costs.

4.3.3.2 Operational costs

The average annual operating costs for each option are summarised below:

| Option | Cost (£M per year) | | | |
|---|---|---|---|---|
| | Routine Inspection & Maintenance | Energy Pumping & Ventilation | Treatment of Tunnel Pump-Out | Total |
| 1a | 1.52 | 3.67 | 2.19 | 7.38 |
| 1b | 1.49 | 3.71 | 1.83 | 7.03 |
| 1c | 1.52 | 3.47 | 2.19 | 7.18 |
| 2a | 1.43 | 3.51 | 1.39 | 6.33 |
| 2b | 1.54 | 3.09 | 2.68 | 7.31 |
| 2c | 1.51 | 3.51 | 1.39 | 6.41 |

The additional operating costs compared with those identified in the TTSS are due to the following factors:

- Modelling has identified significant additional flows that will be intercepted and will therefore need to be pumped and treated.
- Development work has included a review of pumps suitable for pumping out the flows from the tunnel. The energy requirements reflect this more detailed assessment.
- Secondary treatment will incur additional operational costs both for energy and maintenance.
- Provision has been included for cleaning out the tunnel in addition to the flushing arrangements previously assumed.
- Operating costs have been allowed for ventilation of the tunnel and odour control.

4.3.4 Implementation Programme

Detailed implementation programmes for each option have been compiled with key activities identified. The overall durations for each option are as summarised below:

| Option | Start Date | Pre-Construction Phase | Construction Start Date | Construction | Completion Date |
|---|---|---|---|---|---|
| Option 1a | Mar 2007 | 60 months | Feb 2012 | 92 months | Oct 2019 |
| Option 1b | Mar 2007 | 60 months | Feb 2012 | 92 months | Oct 2019 |
| Option 1c | Mar 2007 | 60 months | Feb 2012 | 96 months | Jan 2020 |
| Option 2a | Mar 2007 | 60 months | Feb 2012 | 85 months | Feb 2019 |
| Option 2b | Mar 2007 | 60 months | Feb 2012 | 85 months | Feb 2019 |
| Option 2c | Mar 2007 | 60 months | Feb 2012 | 85 months | Feb 2019 |

The pre-construction activities for all the options include assessed durations for planning, design development, land acquisition, and procurement (tender bid assessment and award). The key activities that govern this period relate to the preparation of the necessary information and material for submission of a planning application and then the period for processing and determination. It is assumed that this will involve a Public Inquiry.

For options 2a – 2c the implementation of the west tunnel is programme critical and therefore governs the overall programme.

4.3.5 Early Phase Implementation

4.3.5.1 Potential solution

The Abbey Mills to Beckton tunnel of Option 1c, together with the treatment works extensions is the only first phase option that could potentially be implemented before the Olympic period in 2012. Other benefits have been identified for this early phasing including delivery of an advanced solution for Abbey Mills (representing 50% of total CSO discharges) 7-8 years before the full scheme with any residual overflows discharged to a less environmentally sensitive location downstream of the Thames Barrier. The implementation programme for this early phase is summarised below:

| Option | Start Date | Pre-Construction Phase | Construction Start Date | Construction | Earliest Completion Date |
|---|---|---|---|---|---|
| Option 1c First phase | January 2007* | 18 months | July 2008 | 45 months | April 2012 |

*subject to early approval to proceed

For this option the earlier start date of January 2007 has been assumed because of the potential urgency to complete these works before the Olympic period. This completion date can only be achieved through a shortened planning process with a local decision and no delay with any other consents required. The target date for obtaining planning permission, including additional treatment at Beckton STW, is April 2008. An extended planning process e.g. call-in and public inquiry, would mean the above date could not be achieved. Note that this option does not require site acquisition.

Achievement of this accelerated programme requires a decision to proceed early in January 2007. An early agreement on funding is also necessary.

The programmed completion date of March 2012 only allows approximately three months time contingency for completion in advance of the Olympics. However there are potential options, based on partial completion of the works that could be invoked if necessary, to ensure sufficient completion prior to the Olympic period if time is lost due to unforeseen construction difficulties. These include omitting the tunnel and shaft lining works, omitting shaft finishing works and reducing pumping station commissioning. These items would then be completed subsequently. In this manner an additional 6 months contingency may be available if necessary.

4.3.5.2 Other options

The implementation of the eastern sections of Option 1a, 1b and 2c is reliant upon land acquisition. This may require purchase by compulsory order and will therefore be a protracted process, significantly delaying the start of construction. The planning process is also likely to be more complex. This almost certainly rules out an early phase of these options being ready in time for the Olympics.

Implementation of the eastern tunnel sections of options 2a and 2b does not require site acquisition, however they are both very large diameter tunnels. Although technically feasible the launch and recovery of such large Tunnel Boring Machines (TBMs) is rarely carried out from deep shafts and is also considered to require extensive facilitation works such as the construction of TBM launch and recovery chambers. Therefore the overall construction will be more risky and could not be recommended as an early phase of work to be ready in time for the Olympics.

## 4.4 Climate Change

The impact of predicted climate change on the performance of each solution has been considered up to the 2020s and 2080s. Previous climate change sensitivity testing, undertaken in 2004 for the TTSS studies, showed that predicted increases in river temperature were by far the biggest factor affecting the DO objectives in the Tideway. Increased temperature both increases reaction rates, so accelerating biodegradation (and hence de-oxygenation), and renders the oxygen less soluble in water.

The impact of temperature increases on solution compliance was considered for climate change up to the 2020s. The increase in water temperature showed that only Option 1a and its variants could still achieve compliance with the DO objectives, whereas Option 2a and its variants all failed. Without 2020's climate change considered, all solutions complied with the DO objectives.

Changing rainfall patterns were also considered for the climate change analysis up to 2080's. This scenario included further temperature increases as well as sea level rise predictions and a factoring of the storm events to include more intense, larger summer storms but on a less frequent basis. The impact of the changed rainfall was to improve compliance due to fewer discharges, but with the further increased temperatures included, none of the solutions assessed would meet compliance with climate change to 2080 factored in; however, it is acknowledged that this would be likely to occur even if all CSO discharges were removed and hence is not a discriminator between options.

## 4.5 Tideway Sewage Treatment Works (STW) Review

A review of the Tideway STW Upgrades in conjunction with revised river quality modelling and to meet the requirement for treatment of tunnel flows has given an optimised and better-balanced proposal. The tables below compare the currently approved upgrades compared with that now proposed.

An important aspect of this work is that these revisions are essential if the target river quality standards are to be achieved.

Note the figures for Dry Weather Flow (DWF) and Flow to Full Treatment (FTFT) include for growth up to 2021 in line with the request to consider forecast of growth. Previous proposals had only looked as far as 2016. Formal agreement of these changes is required together with consideration of any funding implications although it should be noted that apart from the provision for additional growth the cost changes are broadly neutral.

**Consents Assumed at Final Determination – December 2004**

| | | | | Consent (mg/l) | |
|---|---|---|---|---|---|
| STW | DWF (Ml/d) | FTFT (Ml/d) | xDWF | BOD (5) | AmmN |
| Mogden | 559 | 1075 | 2.5 | 11 | 1 |
| Beckton | 1344 | 1800 | 1.7 | 5 | 1 |
| Crossness | 597 | 1485 | 3.6 | 5 | 1 |
| Long Reach | 186 | 311 | 1.8 | 15 | 15 |
| Riverside | 103 | 216 | 2.6 | 7 | 7 |

**Consents for STW extensions now proposed**

| | | | | Consent (mg/l) | |
|---|---|---|---|---|---|
| STW | DWF (Ml/d) (1) | FTFT (Ml/d) (2) | xDWF (3) | BOD (5) | AmmN |
| Mogden | 559 | 1064 | 2.5 | 11 | 1 |
| Beckton* | 1344 | 2336 | 2.6 | 8 | 1 |
| Crossness | 597 | 1118 | 2.5 | 8 | 1 |
| Long Reach | 186 | 338 | 2.0 | 10 | 3 |
| Riverside | 103 | 206 | 2.5 | 8 | 1 |

* depends on tunnel option e.g. figures shown indicate cost of treatment requirements for Option 1a & 1c tunnel treatment.

## 4.6 Risks & Issues

As all the options incorporate the construction of large tunnels, deep shafts, and the interception works for the CSOs, many of the risks are common. In general the construction risks can be managed by invoking adequate strategic site investigation works and employing best construction practice. The main differentiating risks and issues between the options are listed below.

### 4.6.1 Land acquisition

All the main options require acquisition of land for at least some of the main shaft sites. Acquisition is programme critical for the pre-construction activities as well as an essential pre-cursor to construction itself. Should the identified sites become unavailable or acquisition severely delayed, then significant additional cost and delay will be incurred by virtue of identification and acquisition of alternative sites, redesign of significant elements and less efficient construction. Although negotiated land purchase will be investigated this will need to be backed-up by the potential use of Compulsory Purchase Orders where there are no other alternative sites.

### 4.6.2 CSO Interception

Options 2a – 2c do not intercept the CSOs in the central section of the tidal Thames, therefore these would continue to discharge unimpeded. Although there would be a reduction in overall volume of discharge and impact on the Tideway, there would be no reduction in the frequency of discharge, that is, the number of spill day events. These options do not comply with the DO objectives for sustainable fish populations when climate change implications are taken into account at 2020. It should be noted that Option 2 (the two tunnel solutions) is not designed to be converted to a full tunnel for picking up the unconnected CSOs.

### 4.6.3 West Tunnel Pump-out

The west tunnel of Options 2a – 2c is isolated from the main sewage treatment works, located in the east of the catchment. Therefore intercepted flow can only be pumped out to the intercepting sewers and on to the works for treatment after the event has ceased and flows return to normal. Careful control of the pump-out regime would be required to ensure that downstream flooding or overflow to the river does not occur. The average flow in the interceptor sewers will obviously increase during this period of pump-out and should another event occur there is a risk that the volume of discharge will be greater from the un-connected

CSOs. This increase in average flows in the interceptor sewers effectively reduces spare capacity that would otherwise be available to service future development.

It may be possible to partially mitigate the effects of not intercepting the CSOs in the middle section of the Tidal Thames by continued use of the 'Bubblers' (oxygen injection) and deployment of the new litter collection vessels. It is considered unlikely that these measures will achieve the same performance as intercepting the flows and as the litter vessels are not yet operational it is difficult to assess the comparative benefits.

#### 4.6.4 Ground conditions

The tunnel route between Abbey Mills and Charlton generally follows the Lee Valley. The geology has a higher level of fault and disturbance and is therefore more variable and unpredictable. This aspect will increase construction risk. However the geology for the route directly between Abbey Mills and Beckton is believed to be more predictable and therefore the risk is reduced.

Generally the geology for the tunnel routes following the River Thames is reasonably well understood and therefore predictable. However there will be zones, particularly in the areas of the confluences with the lost rivers, where variability is greater. This may impact on the CSO shafts and interconnecting tunnels in the central section. Therefore the implementation of specialist geotechnical works, such as ground freezing, has been included in the scope and budget estimates. Hence an extensive geotechnical investigation and site investigation will be required for all options.

#### 4.6.5 Traffic management

Options 1a, 1b and 1c incorporate significantly more CSO interception works than the other options as they intercept 36 CSOs. These options will therefore involve more work in the highways, which is more likely to be subject to delay as a result of services diversions and accommodation of traffic management issues. These risks can be largely mitigated by advance planning and liaison with stakeholders.

#### 4.6.6 Odour Control

Odour issues associated with the tunnel options have been investigated and proposals identified to deal with potential risks. Further work is required to undertake a more detailed assessment but sufficient work has been carried out to confirm that it is not believed the issue is insurmountable for the majority of tunnel options.

#### 4.6.7 Large tunnel settlement risks

The tunnel route directly between Abbey Mills and Beckton will cross under the cable tunnels, currently under construction, near Abbey Mills. Similarly the direct tunnel route between Abbey Mills and Beckton will also cross under two railways. The larger 13m and 10m diameter tunnels would present a greater risk in this respect and although further analysis may show the effect of these tunnels to be acceptable through use of deeper tunnels, at this stage however it must be considered a significant concern.

## 4.7 SUMMARY

#### 4.7.1 Option 1 – Full-length Tunnel

Option 1a meets the quality objectives but does not entail a viable first phase for early implementation. The Abbey Mills to Charlton section of the tunnel will be subject to higher construction risk because of the more difficult geology of the Lee Valley.

Option 1b meets the DO objectives but allows a greater frequency and volume of discharge to the Tideway. Similar to Option 1a it does not entail a viable first phase for early implementation and is subject to the difficult geology of the Lee Valley. It also does not have sufficient hydraulic capacity to transfer all Abbey Mills CSO flows to Beckton. Therefore discharge to the River Lee will still occur.

Option 1c is the only option that meets all the quality objectives and has potential for early first phase delivery. Implementation of the Abbey Mills to Beckton section is the only first phase option that could potentially be delivered by the Olympic period. However the decision to proceed must be granted in January 2007.

This first phase with extensions at Beckton STW is potentially viable as a stand-alone scheme in advance of implementing the main spine tunnel along the Thames. It would enable the transfer of Abbey Mills CSO flows to Beckton and prevent discharge to the River Lee. However this would result in a higher frequency of untreated discharge at Beckton compared with the full-length tunnel. This may be acceptable as an interim provision, however it may not be for the longer term.

The route of this eastern section of Option 1c also avoids the higher risk geology of the Lee Valley.

#### 4.7.2 Option 2 – East/West Tunnel

Options 2a, 2b and 2c do not meet the DO objectives for sustainable fish populations when possible climate change predictions are taken into account and do not reduce the frequency of discharge from the sewer system as a whole. Pump-out from the West tunnel is operationally complex and incurs the risk of increased frequency or volume of discharge from downstream CSOs.

It is unlikely that small-scale measures (use of Bubblers and litter collection vessels) can fully mitigate the effects of not intercepting the CSOs in the middle section of the Tidal Thames.

The East tunnel sections of Options 2a and 2b are not considered viable first phases for early implementation. The 13m tunnel for Option 2a will have an unacceptable impact on the new cable tunnels and the 10m tunnel for Option 2b will have a significant impact, with no opportunity to invoke protective measures.

#### 4.7.3 Peer Review

The tunnelling and shaft construction of the options has been subject to peer review by a renowned European contractor experienced in such works. The overall conclusions of this peer review support the current proposals as practical and robust. It was also confirmed that the proposed tunnelling works are within the current envelope of construction technology. Recommendations for potential improvements were also made, based on alternative main shaft construction methods and subtle changes to the route of the main tunnel. These will be considered at the next stage of the project and adopted if found to be beneficial on cost or to the programme.

# 5 PLANNING & ENVIRONMENT

## 5.1 OVERVIEW

The key planning and environmental impacts divide into those associated with construction and those with the operation of Tideway Tunnel and associated treatment. Given the scale of the tunnel and the relatively constrained nature of Greater London, the construction impacts have the potential to be considerable and must therefore be fully assessed and mitigated where feasible. In this regard the construction stage could be over a significant period and therefore the associated impacts are not short term.

In reviewing any impacts for the construction of the scheme it must be borne in mind that the project is underpinned by a substantial environmental benefit in terms of improvements to water quality in the Thames Tideway supported by detailed modelling of the catchment and the River.

The main Planning & Environmental report addresses all of the issues in relation to both constructional and operational stages, and in relation to the four component parts. The specific issues the report identifies are as follows: -

- Open Space & Metropolitan Open Land (MOL)
- Energy Use & Carbon Dioxide
- Local Air Quality: Odour
- Regeneration Objectives
- Water Quality
- Biodiversity
- Wastes
- Contamination
- Noise and Vibration
- Traffic and Transportation
- Archaeology & Cultural Heritage
- Flood Risk and Climate Change Response

All the above have been considered but for the purposes of this summary document only selected key points are covered in the following notes.

### 5.1.1 Construction on Open Space and Metropolitan Open Land (MOL)

Open space and MOL are afforded high levels of protection and any losses require special justification. The Tideway enhancement gains which underpin this project will help in the justification. However, loss of public open space will be contentious during both construction and once the Tideway Tunnel is operational and therefore represents a planning risk. Minimising the duration of works and the impact of any permanent works would be recommended as a form of mitigation. Compensatory provision may also be required.

MOL is not considered an overriding planning constraint, although any development on MOL would need to be fully justified

### 5.1.2 Energy Use

Implementation of the project will involve energy demands during construction. Once operational the key energy demand relates to pump out. As a major development there will be a requirement to consider a minimum of 10% of the total energy need from an on-site renewable source. This target figure is likely to rise to 20% and will need to be provided at Beckton, as this is the point of pump out. No overriding planning risk is identified on this issue provided planning permission is granted for renewable proposals.

5.1.3 Local Air Quality (Odour)

The CSOs will not introduce any additional odour issues over and above those already present at the existing CSO sites. The shaft sites do however raise odour potential although an engineering solution is proposed whereby the shaft sites close to sensitive receptors including parks and residential uses will be designed to draw air into the shafts with extraction and treatment at locations where this can be provided, thereby minimising odour.

The final area of odour risk relates to any pump out and treatment works at Beckton. In this regard an odour neutral position will be sought and should be achievable via an engineered solution.

5.1.4 Regeneration

The London Thames Gateway Development Corporation (LTGDC) supported by Government and the Mayor of London is promoting a programme of regeneration in and around the Beckton area. It is clear that the regeneration objectives for the area will impact on the nature of development that will be permitted in connection with the provision of additional sewage treatment works at Beckton. To address this issue Thames Water are working with LTGDC, LB Newham, and the GLA to examine whether alternative arrangements can produce a more compact layout with a smaller land take and potentially complemented by commercial development.

There is backing for such an approach from the Secretary of State's recently published Interim Plan for the Thames Gateway and the London Plan but there are complex implementation issues that require further investigation. This approach does introduce an increased planning risk in respect of any proposals for a conventional layout for expansion of the existing treatment works. Any planning and regeneration objectives along these lines will need to be weighed against any greater certainty of delivery that is inherent to a more conventional works proposal. In any event, it is expected that odour minimisation from any new development will be a priority for the local and strategic planning authorities.

5.1.5 Noise and Vibration

The main tunnel will be between 40 and 80 metres in depth. This depth is likely to be sufficient to prevent any significant issues in terms of noise and vibration on or close to the surface. Aside from the issues of excavation arising, the horizontal element of the tunnel is unlikely to raise any major impacts. However, excavation of the tunnel is reliant on the shaft sites and all arisings will come to the surface via these points.

Some of the shaft sites are close to sensitive receptors (residential especially) and Listed Buildings. Accordingly, special attention will need to be paid in terms of construction methodologies and working hours, which will be limited in the most sensitive locations. This approach also applies to the CSO sites, albeit to a lesser extent reflecting the restricted levels of excavation associated with these sites.

5.1.6 Traffic and Transportation

The key issues relate to disruption from street works and means of transport for removal of excavation arisings. This latter issue also encompasses waste related issues. Disruption is likely to be greater for work in the central London area.

The plan is to remove excavation arisings from shaft sites via River barge and therefore this removes a substantial level of potential HGV traffic. Careful construction and traffic management practices would need to be employed to ensure the following: -

i. The duration of works is kept to a minimum
ii. Separate works are coordinated
iii. Use of river barges is optimised for both import and export of materials

Subject to the careful implementation of such measures the transport related issues are considered challenging but ultimately resolvable.

5.1.7 Land Acquisition

The assured route in which to acquire the land needed for the Tideway Tunnel will be to proceed by way of compulsory purchase. This will have impacts for the project in terms of both programming and costs. Should CPO powers need to be invoked this is likely to run in parallel with the planning process. Negotiations with stakeholders and the planning process could still continue in parallel during the CPO process.

5.1.8 Other Issues

These include what are broadly regarded as relatively modest adverse environmental impacts relating to contamination, biodiversity, archaeology and flood risk. Subject to careful mitigation and design all of these issues can be addressed.

All options considered in this report will require an Environmental Impact Assessment and therefore no part of the proposals could be promoted as Permitted Development (i.e. exempt from Planning Permission). Specific planning permission will therefore need to be sought for all works. There is also a range of procedural issues and consents that will need to be addressed.

Various other consents, licences and easements will be required before work can be undertaken.

## 5.2 PLANNING STRATEGY

Planning advice suggests that planning applications will need to be submitted to all of the Boroughs on the tunnel route, even if there are no above ground works in a given Borough. In the case of all Tideway Tunnel options this will involve the submission of planning applications to the constituent Boroughs. This introduces the following risks: -

1. Refusal of all or part of the tunnel, which could potentially stop or delay the whole scheme.
2. Delays as individual applications are determined to different LPA timetables.
3. Unacceptable and inconsistent planning conditions imposed by different Boroughs.

These risks increase with the number of Boroughs involved and therefore are lower for the two tunnel solutions. In the case of the Abbey Mills to Beckton link, as a first phase, the risks are further reduced as any planning decision could potentially be made by a combination of the Borough (Newham) and the LTGDC. In timescale terms, local approval is attractive in all options though unlikely to be realistic in all but the Abbey Mills to Beckton link. In all cases extensive and early stakeholder engagement reduces the planning risk and should speed up the determination process.

The alternative to local determination is Secretary of State Call–in and the determination of a series of individual planning applications by Public Inquiry in accordance with relatively new, and largely untested, procedures for Major Infrastructure Projects. This process is intended to streamline procedures to fast track projects such as the Tideway Tunnel. In light of the relative infancy of these procedures the extent to which applications are fast tracked in comparison with previous procedures is unknown.

It is understood that local determination may be achievable for an Abbey Mills to Beckton link subject to proposals at Beckton being acceptable to LTGDC and LB Newham. This raises the possibility of a quick planning approval obtained locally. The environmental issues associated with this short tunnel section are also relatively limited and much of the baseline data is already known. A genuinely fast-tracked permission may therefore be possible for this link.

Given that Abbey Mills accounts for 50% of all CSO spills this option potentially offers significant environmental gains and a relatively rapid consenting timeframe.

## 5.3 CONSULTATION

An initial process of consultation has been undertaken with key stakeholders at which the proposals under consideration were presented and feedback from the participants noted. The importance of consultation is recognised within the planning process and will be part of the work undertaken prior to the submission of a planning application.

## 5.4 SUMMARY

This is clearly a challenging project in terms of both engineering and planning and environmental constraints. Whilst none of the potential planning and environmental adverse impacts are considered insurmountable they will require careful and detailed mitigation. The key impacts will relate to loss of open space and transport. The design of remaining permanent works on public open space once the Tideway Tunnel is operational will determine, in part, any local opposition. With discreet above ground works and potential for reuse any objections should be minimised.

The ability to resolve planning issues associated with the extension required at Beckton STW will be critical to the scheme. The key issues are aspirations for regeneration of the area and minimisation of odour associated with an extended treatment plant.

Land acquisition for the tunnel shaft sites may require CPO powers. Other consents relating to development on Crown Land (the river bed) and the requisite easements on many other sites will also be required. Both of these issues will introduce potential issues of delay and compensation.

In terms of consenting for the project, widespread stakeholder engagement will be essential. The scale of the project may prevent local consensus being achieved on any full Tideway Tunnel. ‘Call-in’ using the relatively new and largely untested Major Infrastructure Projects procedures appears to be the most likely consenting procedure for this project. That said, an Abbey Mills to Beckton link is considered promotable in its own right and capable of gaining a relatively prompt local obtained planning permission. This is however subject to the proviso that local regeneration concerns are addressed.

# 6 COST BENEFIT

## 6.1 OVERVIEW

The major purpose of the work of the cost benefit group was to produce an assessment of the costs and benefits of the options under consideration. Early meetings of the group focussed on reviewing the changes that had taken place since the TTSS assessment to determine whether they were sufficient to drive a requirement for new survey work rather than a simple updating of the previous analysis. The group concluded that it would be beneficial to undertake a new stated preference survey and to commission a review of previous work on environmental costs and market benefits.

In all, the group commissioned three separate pieces of work (the other information required, costs of options, was provided by the solutions group).

- An assessment and valuation of environmental benefits, as defined by the objectives, modelling and compliance group, undertaken by Eftec. A stated preference study was commissioned to inform this aspect. The benefits included in this study are reduction in fish kills, reduction in elevated health risk and reduction in sewage-derived litter
- An assessment and valuation of environmental and social impacts (as identified by the environment and planning group) and market benefits, undertaken by Entec.
- A cost benefit analysis to inform the comparison of the principal two options, and variants as appropriate, undertaken by NERA.

## 6.2 RESULTS

All three studies reported in December 2006. The main findings were as follows:

### 6.2.1 An Assessment and Valuation of Environmental Benefits (Eftec)

Eftec used a contingent valuation study to elicit peoples' preferences expressed as their willingness to pay (WTP) to reduce the combined impacts of the CSO discharges (that is the potentially harmful impacts on fish and other wildlife, the increased health risk and the discharge of sewage-derived litter to the river) on the Tideway. The reduction in impacts was described in terms of the predicted benefits afforded by the three main alternative engineering solutions, a large diameter tunnel (7.2m) running from Hammersmith to Beckton with a spur to Abbey Mills sewage pumping station, a smaller diameter tunnel (6m) of the same length and two large diameter tunnels in the West (Hammersmith to Heathwall) and East (Abbey Mills to Beckton) of the Tideway. Respondents were also asked whether and what they would be willing to pay to ensure that part of the scheme was delivered early enough to avoid the risk of a CSO discharge from Abbey Mills sewage pumping station during the Olympics.

The questionnaire was administered to a total of 875 respondents (599 Thames Water customers and 276 customers of other water companies). This enabled the aggregation of benefits within two jurisdictions:

- The benefits jurisdiction - to identify all of the benefits afforded by the proposed Tideway improvements
- The administrative jurisdiction - to identify only those benefits held by Thames Water customers, the group most likely to have to pay for the improvements through their water bills.

Aggregation was undertaken using both a derived distance decay function with explanatory variables relating to distance from the Tideway and socio-economic class and the sample mean. The survey results are given in the table below detailing the non-market benefits by option.

| Option | Benefits Jurisdiction (English households) | | Administrative Jurisdiction (TW customer Households)[1] | |
|---|---|---|---|---|
| | Per household per year (£) | All households per year (£m) | Per household per year (£) | All households per year (£m) |
| Large diameter tunnel (7.2m) | 8.52 | 174 | 13.02 | 66 |
| Small diameter tunnel (6m) | 4.00 | 82 | 7.44 | 38 |
| Two tunnels | 2.10 | 43 | 5.17 | 26 |
| To avoid CSO discharge during 2012 Olympics | 4.90[2,3] | | 4.28[2,3] | |

All figures in 2006 prices
[1]*This benefits jurisdiction differs across each of the options for which willingness to pay has been estimated: for Option (1), and by implication Option 1c and Option 1c (phased), this refers to all households in England; for Option 1b this refers to all households within a 260 mile radius of the Thames, and for Option 2 refers to all households within a 170 mile radius of the Thames.*
[2] *Non-TW customers*
[3] *Aggregated on basis of sample mean rather than distance decay relationship*

WTP figures were found to be consistently higher for the larger diameter tunnel than the other two engineering options. Use of the derived distance decay function reduces the aggregate WTP compared to the values derived from the simple mean WTP. There is a positive willingness to pay for an earlier 'Olympics solution' from a proportion of the respondents.

### 6.2.2 Environmental Costs and Market Benefits (Entec)

Entec distinguished between environmental and social impacts during construction and operation of the different tunnel options, the most significant occurring during the construction phase. The report identifies a range of potential environmental costs arising from the tunnel, only some of which could be expressed as monetary values. The most significant of these construction impacts were the energy embodied in construction materials, including the energy required to extract, process and transport the materials to site, the social costs arising from traffic delays and the environmental costs arising from the transport and disposal of construction waste. The effect of land take on recreation, visual amenity, biodiversity and archaeology could also be important although of more minor significance.

During tunnel operation some of the potentially most significant environmental issues are considered within the Eftec study. Of the environmental impacts assessed by Entec, the potentially most significant was the reduction in flood risk, although there is considerable uncertainty surrounding the levels of risk and the values associated with the potential impact. The effect on biodiversity was noted as being of minor significance because of the potential loss of intertidal mud flats and rough grassland and reedbeds at Beckton sewage treatment works, although this impact could not be valued.

The report also concluded that there was a potential minor market benefit associated with reduced use of the bubbler and skimmer vessels and chemical dosing of peroxide, currently undertaken to counteract the effect of the CSOs.

A summary of the financial benefits and non-financial costs derived by Entec (2006) is reported in NERA (2006) and reproduced in the table below.

| Option | Financial Costs: Capex (£m) | Financial Costs: Opex (£m) | Financial Benefits (£m) | Non-Market Costs (£m) |
|---|---|---|---|---|
| 1a | 2364 | 366 | 41 | 108 |
| 1b | 2262 | 347 | 40 | 99 |
| 1c | 2453 | 356 | 41 | 108 |
| 1c phased | 2460 | 363 | 42 | 109 |
| 2a | 1816 | 310 | 30 | 61 |
| 2b | 1878 | 361 | 30 | 65 |
| 2c | 1907 | 314 | 30 | 57 |

*All figures in 2006 prices totalled over 60 years*

For comparison the financial costs from the Solutions group (Capex and Opex) are also presented. It is evident that the financial benefits and non-market costs identified by Entec (2006) are considerably less than the financial costs of the different engineering options.

6.2.3 Tideway Tunnel Cost Benefit Analysis (NERA)

NERA used the outputs described above and initial cost estimates to undertake a cost benefit analysis.

All cost and benefit figures were monetised over a 60-year time horizon. Changes in prices were allowed for, where these might be expected to be different from general inflation, and adjustments made where appropriate for differences between factor and market prices. The Green Book recommended discount rate of 3.5% real per year for the first thirty years and declining thereafter was used to produce the comparative figures of Net Present Value and Benefit Cost Ratio shown in the table below.

| | Benefits jurisdiction (All England[1] households) | | | | Administrative jurisdiction (TW customer households) | | | |
|---|---|---|---|---|---|---|---|---|
| Option | NPV (£ million) | NPV Rank | Benefit/Cost ratio | Benefit/Cost ratio rank | NPV (£ million) | NPV Rank | Benefit/Cost ratio | Benefit/Cost ratio rank |
| 1a | 2009 | 1 | 2.04 | 1 | -423 | 1 | 0.78 | 1 |
| 1b | 14 | 4 | 1.01 | 4 | -980 | 7 | 0.47 | 4 |
| 1c[2] | 1970 | 2 | 2.00 | 2 | -463 | 2 | 0.76 | 2 |
| 1c phased[2] | 1882 | 3 | 1.92 | 3 | -550 | 3 | 0.73 | 3 |
| 2a | -447 | 5 | 0.69 | 5 | -826 | 4 | 0.42 | 5 |
| 2b | -502 | 6 | 0.66 | 6 | -881 | 5 | 0.41 | 6 |
| 2c | -516 | 7 | 0.66 | 7 | -895 | 6 | 0.40 | 7 |

All figures in 2006 prices
[1]*This benefits jurisdiction differs across each of the options for which willingness to pay has been estimated: for Option (1), and by implication Option 1c and Option 1c (phased), this refers to all households in England; for Option 1b this refers to all households within a 260 mile radius of the Thames, and for Option 2 refers to all households within a 170 mile radius of the Thames.*
[2]*1c does not include any Olympic related benefit estimate in this table*

None of the options have a positive NPV for the administrative jurisdiction. However as noted by NERA, '*a full cost benefits analysis takes account of all benefits, whoever receives them*', hence it is appropriate to consider the benefits jurisdiction. This does not imply that an intervention should go ahead if it passes a cost benefit test on this basis since other considerations, such as distributional impacts, will come to bear in making that decision.

For the benefits jurisdiction, three variants of Option 1 (a, c and c phased) have a positive NPV and are cost beneficial. However there is little difference between them on cost benefit grounds.

Switching analysis was also undertaken. For the benefits jurisdiction, for the three highest-ranking options, costs would have to approximately double relative to the benefits for the NPV to fall to zero. Conversely, benefits for these options would have to fall by approximately half for them to cease to be cost-beneficial.

A number of sensitivity tests were applied to these results, including changes to the time horizon, financial costs, monetised non-financial costs, financial benefits, non-financial benefits and the assumed cost of private financing. Although both a poor outturn on costs or an alternative view of the status of the WTP benefits could reduce the NPVs or cost-benefit ratios, only one of the sensitivity tests alters the rankings of the options significantly. This exception occurs when a higher willingness to pay to reduce the likelihood of a CSO discharge in time for the Olympics is applied. This led to a significantly higher NPV (£4138m) and cost benefit ratio (3.02) for Option 1c (phased) than for Options 1a and 1c (applied to the benefits jurisdiction). However this conclusion must be treated with an element of caution because the median WTP for this option was zero showing that if extra spending for the Olympics option had come up as a referendum, half the sample would have stated zero WTP. Further, the statistical validity of the Olympics WTP has not been explored in sufficient detail as yet because of time constraints.

The Cost Benefit working group is satisfied that the cost benefit analysis studies have been undertaken to a high standard. However the nature of the both the task itself and the methodologies used are uncertain and, despite the high quality of the current studies, a number of significant uncertainties remain. These are discussed in detail in the Cost Benefit working group report.

# 7 IMPACT ON CUSTOMER BILLS AND AFFORDABILITY

## 7.1 IMPACT ON CUSTOMER BILLS

Work carried out by Ofwat using financial modelling against preliminary cost estimates for alternative options has identified the likely impact on customer bills for the alternative options as shown below:

| Option | Maximum Marginal Bill Effect (£) | Year in which the maximum marginal bill impact occurs |
|---|---|---|
| 1a | 43 | 2016 - 2017 |
| 1b | 42 | 2016 - 2017 |
| 1c | 45 | 2016 - 2017 |
| 1c phased | 46 | 2016 - 2017 |
| 2a | 33 | 2016 - 2017 |
| 2b | 32 | 2016 - 2017 |
| 2c | 35 | 2016 - 2017 |

**Modelling approach -** Ofwat has used its Aquarius 3 financial model, version 6.1, which runs over the period to 2029-30, to model the base case and the scenarios constructed from the incremental Thames Tideway option profiles. The base case assumes a future scenario characterised by a benign macro economy and relatively high priority being accorded to the environment.

## 7.2 AFFORDABILITY

Against a rising background level of 'water poverty'[1], the modelled bill increases due to the Thames Tideway Tunnel scheme suggest that its impact may be marginal to overall background increase. Whilst increasing, the total proportion of Thames Water customers suffering from 'water poverty' is likely to be some way below the levels projected for some of the other water and sewerage companies in England and Wales (ranging from 9.5% to 30.4% of households by 2009/10)[2]. Definitions of 'water poverty', however, fail to take account of the impact of high housing costs on the London and South East regions, which could significantly increase the numbers of customers suffering hardship. In the absence of income data specific to Thames Water customers it has not been possible to model this overall impact across the life of the project.

More detailed modelling of alternative charging mechanisms is needed to examine whether the impact on low-income households could be mitigated effectively, efficiently and equitably. Some such mechanisms are currently prevented by legislation or by regulatory policy. This is an industry-wide challenge and is not specific to the Thames Tideway Tunnel scheme. Charging mechanisms and affordability issues are currently being reviewed at Government and Water industry level.

## 7.3 THAMES WATER'S CUSTOMERS' WILLINGNESS TO PAY

As described above, the cost benefit assessment has evaluated benefits across two user populations, the administrative jurisdiction (those who under the current regulatory regime would pay for any improvements) and the benefits jurisdiction (those who would derive benefits from the improvement). Under the benefits jurisdiction, three variants of option 1 are cost-beneficial. However under the administrative jurisdiction none of the options are cost

[1] Water poverty is defined as households spending more than 3% of disposable income on water and sewerage bills (threshold used in quality of life indicators for Defra UK sustainability indicators)
[2] Cross-Government Review of Water Affordability Report, DEFRA 2004, Annex C Table B

beneficial. This calls into question whether Thames Water's customers should be called on to pay for improvements that are justified by the benefits to a wider population. For option 1a, for example, willingness to pay within the Thames Water catchment was reported as some £13, whilst the likely increase in bills is perhaps £43 - a disparity of more than three-fold. This is clearly not to be compared with the cost benefit analysis but it is an assessment worthy of consideration. It certainly suggests that the costs should fall on a wider base than just Thames Water's customers.

# 8 FUNDING AND FINANCE

## 8.1 OVERVIEW

Thames Water has commissioned a specialist consultant (First Economics) to undertake a study looking into how large capital projects could be funded. The study examines whether the current regulatory regime can deal appropriately with such projects and whether alternative approaches or delivery structures (e.g. a PFI-style arrangement) better allocate risk and ensure that both the Company and Ofwat can continue to meet their legal obligations. Expert opinion has been sought to ensure that the recommended options address the concerns of the capital markets such that the desired investment is available at efficient cost when required.

Thames Water recognises that Ofwat will be concerned that possible alternatives to the established financing mechanisms do not place an inappropriate level of risk on customers and that they continue to receive good value for money from capital investment programmes. In this context Ofwat has expressed the view that to the extent that any additional cost is attributable to the 2012 Olympic Games, whether due to increased scope or timing of improvements, then such cost should be borne by those responsible for the Olympics development.

## 8.2 DEFINITION OF FUNDING OPTIONS

The study is being undertaken in two phases. In the first phase large projects were defined and criteria established against which to assess each of the funding options. Ofwat's current mechanism for funding projects was reviewed alongside those developments made by other regulators to deal specifically with large projects. The key findings were that the Tideway project meets the definition of being large and that there is scope to further develop the existing regulatory mechanism in the water sector in the context of large projects to better define and allocate risk, increase certainty and to ensure that overall returns are consistent with the business risk that the Company is asked to assume.

## 8.3 DEVELOPMENT OF FUNDING OPTIONS

In the second phase the alternative funding options are being considered in more detail and tested against the criteria to ensure that capital markets receive an appropriate reward for the risk assumed, that customers do not bear an inappropriate level of risk, that risks are allocated to the party best able to manage them and that both Ofwat and the Company can meet their legal obligations. It is planned that a shortlist of options best meeting the criteria will be discussed with Ofwat in January 2007 to enable agreement to be reached on a preferred funding mechanism such that investment will be available for the Tideway project at the right time.

## 8.4 FUNDING FOR AN EARLY PHASE

Funding remains a key factor that needs to be resolved before the tunnel proposals can be progressed further. This is particularly relevant to the development of an early phase of the scheme in time for the Olympics where a start is required almost immediately. The report identifies the risks to achieving scheme delivery by 2012 (for a first phase of Option 1c). However the financial risk to the company in undertaking such work before the source of funding is identified and confirmed needs to be recognised. It should also be considered in the light of Ofwat's stated policy that companies need to appeal unreasonable/contentious planning requirements if they want the associated expenditure recognised in price limits. Such an appeal in this case would inevitably result in a delay not currently factored into the timetable for the delivery of the first phase.

# 9 CONCLUSIONS

## 9.1 OBJECTIVES

Complete cessation of any intermittent discharges is not a realistic objective or requirement; the options listed for development implicitly recognise that occasional overflows from the network will occur. This is accepted within the UWWTD, compliance with which is an overarching priority, but requires interpretation. Hence for aesthetic and health considerations the target is 'reduction' (to a greater or lesser extent) of adverse impacts. Protection of the ecology is framed in terms of dissolved oxygen, but the situation is more complex since the larger contribution to oxygen depletion is the impact of the continuous STW discharges.

Although network discharges will occur, the proximity of the Abbey Mills pumping station to the Olympic Park and the surrounding regeneration area has implied a secondary objective for there to be 'no discharges from Abbey Mills' which requires diversion of flows elsewhere. This also has the benefit of transferring any residual overflows to a potentially less environmentally sensitive location.

All options have been developed with a view to providing full secondary treatment at the receiving STW, consistent with meeting environmental objectives, and the avoidance at the STW of frequent untreated discharges other than as an interim measure pending a longer-term solution.

## 9.2 OPTIONS

### 9.2.1 Option 1 and variants

Option 1a meets the long-term quality objectives but does not entail a viable first phase for early implementation by 2012, due to the anticipated delays of land acquisition and planning issues at Charlton. Additionally, the Abbey Mills to Charlton section of the tunnel may be subject to higher construction risk because of the uncertain geology of the Lee Valley

Option 1b meets the dissolved oxygen objectives but allows a greater frequency and volume of storm sewage discharge to the Tideway. It therefore does not achieve the same aesthetic or health benefits as 1a, and, similar to option 1a, it does not entail a viable first phase for early implementation and is subject to the uncertain geology of the Lee Valley.

Option 1c is the only option that meets all the long-term quality objectives and offers potential for an early first phase delivery. Implementation of Abbey Mills to Beckton section is the only first phase option that appears to offer any realistic potential in terms of a 2012 delivery. However, this programme is tight, and so the opportunity is only available if the decision to proceed is made almost immediately, for a start in January 2007.

This first phase would enable the transfer of Abbey Mills CSO flows to Beckton and, if pumped at Abbey Mills, obviate any discharges to the River Lee from this site. Without further improvements, this would result in a high frequency of untreated discharge at Beckton that may be acceptable as an interim provision, pending full-length tunnel completion. Although extensions to the treatment provision are planned as a parallel activity this first phase will not be able to reduce the frequency and volume of untreated overflow from a new Beckton discharge to the level needed to fully comply with target objectives met by the full scheme.

The route of this eastern section of Option 1c avoids the higher risk geology of the Lee Valley.

### 9.2.2 Option 2 and variants

None of the option 2 variants address the substantial intermittent discharges in the central section of the tideway, which includes the reach through the City of London. These discharges – some 16 or 17 in number, depending on the sub-variant – will continue to

operate as they do now, discharging approximately ¼ of the total volume on a frequent basis. Furthermore, the tidal movement will carry the impact of these discharges beyond the receiving reach, and so partially negate the benefits of the discharges that are connected and addressed.

The continuation of the non-connected discharges is reflected in the poorer performance of these options in terms of aesthetic and health benefits, even after the impacts are weighted for location. Nonetheless, they do address the Abbey Mills discharge and improve the quality of the western section which is most intensively used for recreation.

Whilst Options 2a, 2b and 2c initially appear to meet the DO objectives for sustainable fish populations, it is predicted that by 2020 the impact of climate change will be such that the objective will not be met. This is common to all variants of Option 2 and again reflects the impact of the non-connected CSOs

The return of stored flows to the existing networks, which are otherwise largely independent in operation is operationally complex and incurs the risk of increased frequency or volume of discharge from downstream CSOs due to there being very little spare capacity available.

The east tunnel sections of Options 2a and 2b are not considered to be as suitable or practicable for early implementation, particularly if compared to option 1c. Although the larger diameter tunnels are technically feasible, there is less experience of their use and there are specific issues, such as in-shaft assembly, which are likely to introduce delays. Furthermore there are concerns that these larger diameter tunnels would need to run at an even greater depth to ensure that there were no adverse impacts on other services. These issues make delivery by 2012 less likely. The storage afforded by Option 2a would, however, be adequate as a ‘stand-alone’ solution to accommodate Abbey Mills discharges.

#### 9.2.3 All options

##### 9.2.3.1 Odour

The operation of the tunnel options, with regard to ventilation potential for odour and flushing, has been investigated in greater detail. Generally options based on single tunnel lengths, such as the West tunnel of Options 2a – 2c and the East tunnel of Options 2a and 2b will be more difficult to flush clean after drain down and will, therefore be more likely to cause odour problems. The sequential drain down and flushing operation that can be employed for Option 1a - 1c will ensure minimal residual deposition and therefore low likelihood of odour generation. A full ventilation system, complete with odour control plant at strategic locations and discharge stacks for venting, is proposed to minimise any potential odour.

##### 9.2.3.2 Treatment

Extension to treatment at the Beckton site is expected to attract potentially restrictive planning conditions. The costs provided so far are those for conventional treatment plant. Should major restructuring or treatment process change be required, then the costs could increase, together with the timetable for delivery.

## 9.3 TIDEWAY STW IMPROVEMENTS

The package of STW improvements currently funded and approved does not appear to offer the best overall fit with a tunnel solution, nor would it fully meet the environmental objectives derived here. A revised package of works is therefore recommended, and these subsequent tunnel conclusions are based on the delivery of the revised package. Should a decision not to proceed with any of the tunnel options be made, the revised works improvement package should still be adopted as it optimises environmental improvements and costs.

## 9.4 COST BENEFIT ASSESSMENT

The willingness-to-pay survey has confirmed that respondents could differentiate between the environmental benefits delivered by the various options, and that they valued the options delivering higher benefits more.

Applying the approved cost benefit methodology, the Option 1 variants demonstrate a positive NPV and a cost benefit ratio greater than 1. Conversely, the Option 2 variants showed a negative NPV and a ratio of less than 1. There was also a willingness to pay more to deliver benefits in time for the Olympics.

The cost benefit assessment indicates a clear differentiation between Options 1 and 2. Within Option 1 there is little difference between Options 1a and 1c until the benefit of early delivery is included. Whilst this is recognised as a less robust assessment, it strongly suggests that Option 1c would rank most highly.

## 9.5 CONSTRUCTION RISKS

All options for the Tideway Tunnel represent a very major construction project. It is exceptional though not entirely unique in terms of its size, complexity and technical challenges. Although the construction methods proposed are in the main tried and tested, it is the scale of the activities to be undertaken that sets this project apart with some aspects of the engineering at the boundaries of what is technically achievable using conventional construction techniques.

As all the options incorporate the construction of tunnels, deep shafts, and the interception works for the CSOs, many of the risks are common. In general the construction risks can be managed by invoking adequate strategic site investigation works and employing best construction practice. The particular risks with the large tunnels that form part of Option 2 variants and other specific ground condition issues are dealt with elsewhere in this report.

There is also the logistical challenge of implementing the work within confined areas available for construction and a congested urban environment.

These aspects have been covered as far as it is possible at this stage of the project development with a full risk review undertaken based on outline design work for the alternative tunnel options. These risks have then been costed using the best information available.

## 9.6 OTHER CONSIDERATIONS

A broad spectrum of other issues has been considered during the option development and assessment. Many of these are considered in detail as appropriate in preceding sections, but key comments are:

- Optimum phasing: An interim solution involving an Abbey Mills-Charlton link was not evaluated in detail beyond determining that compulsory purchase would be required for sufficient land at Charlton to enable construction, and that a major outfall structure involving planning permissions would be required. The Abbey Mills to Beckton link has been evaluated instead and is discussed as the early phase of Option 1c.
- Additional costs of phasing: Considered under 1c (as relative to 1a)
- Affordability: Any of the options will have consequences for affordability, as measured in terms of water poverty.
- Water Framework Directive (WFD): The baseline for the WFD is full implementation of existing directives (i.e. including UWWTD). Beyond this, the study has considered only the draft standards for water quality expressed in terms of dissolved oxygen. No

option delivers the proposed DO standards for 'good quality' but this is more a function of background water quality (and hence related to STW effluent quality) than the impact of the CSOs.

- Climate change and robustness of option: Option 1 variants provide better protection against the predicted consequences of climate change in terms of dissolved oxygen concentrations. Similarly, any revisions to water quality are more likely to impact on option 2 variants. Overall, Options 1a & 1c offer the best robustness simply because a greater volume/flow is transferred to the receiving STW where additional treatment can be implemented if required.
- Regeneration in East London: All options will benefit the regeneration of East London, the only differentiation being phasing. If river quality is a major factor in regeneration then this would favour Option 1c.
- Housing growth: The very large-scale housing developments (Thames Gateway) do not contribute to the CSO issue which these options address, as these are likely to be connected to collecting systems where surface water run-off will be kept separate. As the catchment is largely mature and the intermittent discharges arise as a result of rainfall, redevelopment is considered unlikely to be a factor which differentiates between options
- Sewer Flooding: The anticipated benefits to reduce sewer flooding, from the preliminary assessment made so far, are relatively modest but Option 1 offers better alleviation than option 2
- Planning: Aspiration for regeneration and odour issues are specific concerns with respect to the receiving treatment works at Beckton. Until detailed proposals can be discussed and a planning application is made, the precise requirements or other planning conditions can only be addressed speculatively.
- Sustainability/Carbon footprint: All options will permit some energy recovery from the collected sewage (through processing of sewage sludge), although the opportunity from Option 1 is clearly greater than that from 2. Conversely, however, the energy use of Option 1 is greater than that of Option 2, and this is reflected in higher carbon emissions. Renewable energy options will be considered in detail during the next phase of development including potential to exceed minimum levels required to meet planning guidelines.

## 9.7 OVERALL ASSESSMENT

Option 1c may be marginally the most expensive but it delivers the maximum benefits, with construction risks that are considered manageable, and can offer the possibility of an early phased solution, which could be operational as early as 2012.

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