Thames Tideway Tunnel
Thames Water Utilities Limited

Application for Development Consent

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Tackling London's Sewer Overflows

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Thames Tideway Tunnel
Creating a cleaner, healthier River Thames

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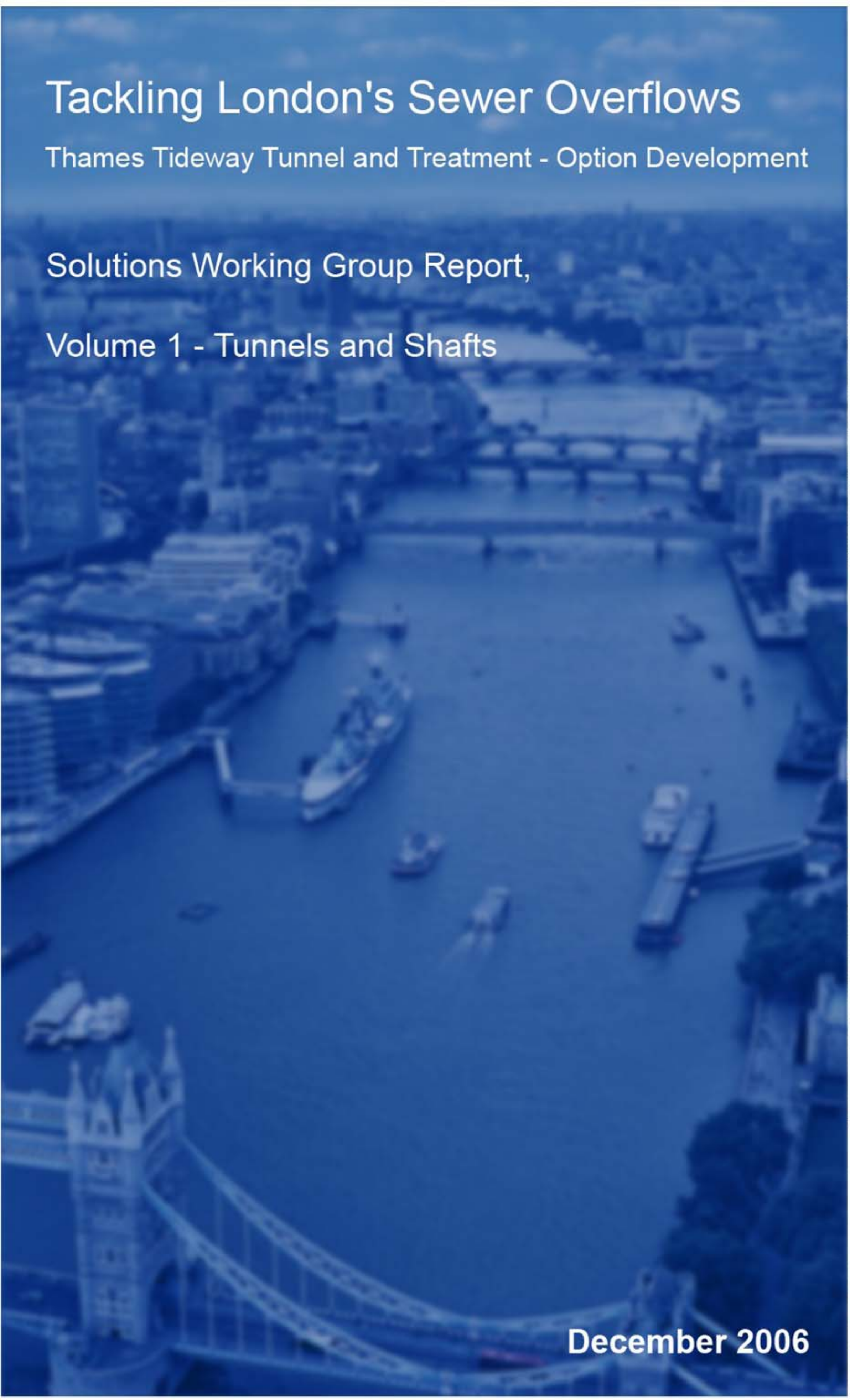
Tackling London's Sewer Overflows

Thames Tideway Tunnel and Treatment - Option Development

Thames Tideway

Solutions Working Group Report,

Volume 1 - Tunnels and Shafts



December 2006

Thames Water

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0 EXECUTIVE SUMMARY

0.1 INTRODUCTION

In 2005, The Thames Tideway Strategic Study (TTSS) group reported on the potential solutions which could be developed to tackle the problems of Combined Sewer Overflow (CSO) discharges to the Thames Tideway. Since the TTS Studies reported in 2005, an instruction from Defra has been received to further investigate and compare two main options for tackling the CSO discharges to the Thames Tideway. These two main options, each with three variants are developments of the TTSS recommended option A (ref), which included for 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 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. The location for treatment has been determined taking various factors into account and confirmed as part of this development work.

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.

0.2 OPTION OVERVIEW

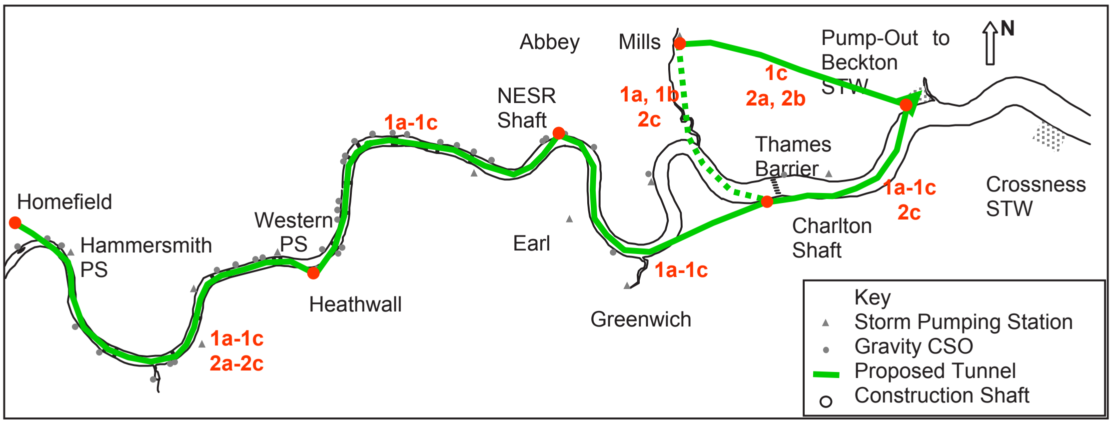
0.2.1 Options

The two principal options, each with three variants, 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 has been 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 being 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.

The various routes for each option are detailed in the diagram below:



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 2. Abbey Mills to Beckton via Charlton – 7.2m diameter
1b	1. Abbey Mills to Charlton– 6.0m Diameter 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 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.

0.2.2 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 (7.2metre diameter) tunnel solution. The performance of other options and variants will be proportionately less with the reduced storage of the alternative full tunnel (6m 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.

0.2.3 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.

0.2.4 Tunnel draindown & pump-out

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

0.2.5 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. It also means that a better balance of treatment can be provided between the main Tideway STW sites and is a more logical fit with flows received from the catchment.

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.

0.2.6 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.

0.2.7 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 dependant on gaining early planning permissions for the proposed works. This is a key factor in determining the programme for early delivery.

0.2.8 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.

0.3 Option Assessment

0.3.1 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.

0.3.2 Environmental Performance

The two main tunnel options, namely the complete 7.2 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.

0.3.2.1 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 that 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-connectd 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.

0.3.2.2 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 standard 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.

0.3.2.3 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 complaint 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.

0.3.2.4 Climate Change

The impact of predicted climate change on the performance of each solution has been considered up to the 2020's and 2080's.

The impact of temperature increases on solution compliance was considered for climate change up to 2020's. 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.

Climate change analysis up to 2080's was also considered. This scenario included further temperature increases as well as sea level rise predictions and a factoring of the storm events. 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.

0.3.3 Cost Estimates (Tunnel & Treatment)

0.3.3.1 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 been 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 likelihood’s of occurrence, cost and time impact. Three point estimate 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.

0.3.3.2 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.

0.3.4 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.

0.3.5 Early Phase Implementation

0.3.5.1 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.

0.3.5.2 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 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 do 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.

0.4 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.

0.5 Risks & 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 listed below:

1. All the main options require acquisition of land for 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.

2. Options 2a – 2c do not intercept the CSOs in the central section, therefore these would continue to discharge unimpeded to the River Thames. Although there would be a reduction in annual volume of discharge to the Tideway, there would be no reduction in the frequency of discharge, that is, the number of spill day events. These options also do not comply with the DO objectives for sustainable fish populations.

3. The west tunnel of Options 2a – 2c is isolated from the main sewage treatment works, which are 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, flows return to normal and there is spare capacity 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.

4. 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. However the geology for the route directly between Abbey Mills and Beckton is more predictable and therefore the risk is reduced.

5. Generally the geology for the tunnel routes following the River Thames is reasonably well understood and therefore more predictable. However there will be zones, particularly in the areas of the confluences with the lost rivers, 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, such as ground freezing, has been included in the scope and budget estimates. The precise nature of such facilitation works would be determined following a detailed, strategic geotechnical and site investigation

6. Of particular concern is the launching and recovery of the Tunnel Boring Machines (TBMs) from deep shafts for the large tunnels of the east tunnel of Options 2a – 2c. 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. However more confidence can be expressed for the construction of the 6m and 7.2m diameter tunnels of Options 1a – 1c as there is more experience of the launch and recovery of the TBMs of this size from deep shafts.

7. Also launching of the 10m and 13m diameter TBMs, for the east tunnel of Options 2a – 2c, from the shafts would require the construction of significant underground chambers to facilitate TBM assembly. Excavation of these chambers would potentially involve large areas of unsupported ground during the construction sequence which would require extensive geotechnical works. Therefore the launching of the these TBMs would incur significantly more risk.

8. Options 1a, 1b and 1c incorporate significantly more CSO interception works than the other options as they intercept all the category 1 and 2 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.

9. A particular issue is the proposed Victoria Embankment Project, which includes the reduction in width of the highway and the creation of a promenade adjacent to the River Thames. The target completion date is 2010. This proposal would have a significant impact on the CSO interception works for this section, however there is the opportunity for collaborative working. The interceptions works could be brought forward to accommodate the Victoria Embankment Project in advance of the main tunnel works and then connected at a later date. Alternatively the interception works could be carried according to the current programmes in early 2017, some 7 years after completion of the Victoria Embankment Project, located mainly in the promenade section with correspondingly less impact on traffic.

10. The CSO interception works as currently detailed for Brixton and Clapham Storm Relief Sewers would have a significant impact on traffic at Vauxhall. There are potential alternatives, based on locating the drop shaft in the foreshore adjacent to Vauxhall Bridge that could be implemented to reduce impact. These options would require development at the next stage of the project and in particular the relevant approvals from the Port of London Authority.

11. For an early phase of Options 1a, 1b and 2c, with the transfer of Abbey Mills CSO flows to overflow Beckton this would require the tunnel route and hence the main shaft at Charlton to be surcharged. When the full scheme is in place isolating penstocks would need to be closed during the event to prevent surcharge of the upstream CSOs and the Charlton CSO. This would be operationally more complex and significant flooding would result if these isolating penstocks failed to open. The main shaft would also have to be extended above ground to prevent release of flow from the roof covers. The extended programme for an early phase would mean that work could not be completed in time for the Olympics.

12. The tunnel route directly between Abbey Mills and Beckton will cross under the cable tunnels, currently under construction, near Abbey Mills. The predicted ground movements and deformation curvature are very significant for the 13m diameter tunnel and will therefore be unacceptable. The potential impact from the 10m tunnels will be less, but still quite significant. The completed tunnels will house high voltage cables and a mini railway (for inspection purposes) and will not therefore be amenable to retrofit strengthening requirements. As there is no current direction for implementation of the Tideway scheme advance works cannot be incorporated in the current construction of the cable tunnels. It is likely therefore that the 7.2m tunnel would be the only practical option.

13. The tunnel route directly between Abbey Mills and Beckton will also cross under two railways. The crossing angle will unavoidably be oblique and therefore exacerbate the potential impact of ground movements on the tracks. The likely impact of the 13m and 10m diameter tunnels will be significant, whereas the impact of the 7.2m will be within manageable limits.

0.6 CONCLUSIONS

0.6.1 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.

0.6.2 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.

0.6.3 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.

1 INTRODUCTION

In the letter to Thames Water dated 27th July 2006, Ian Pearson, the Minister of State for Climate Change & Environment, asked Thames 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 Sewage Treatment Works (STWs).

The objective of this phase of work has been to develop proposals that will deliver the required improvements to the Thames Tideway. Two main alternative storage tunnel options designed to collect discharges from London's major combined sewer overflows (CSOs) and transfer the flows for treatment 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 be considered in conjunction with work already approved for uprating Tideway Sewage Treatment Works (STWs).

Working Groups were set up to deal with particular aspects of the Tideway development and also the project teams currently working on the AMP4/5 Tideway STW Upgrades and other related Tideway work. 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, Solutions, Planning & Environment and Cost Benefit.* There has been a separate piece of work to consider funding and finance.

The ***Solutions Group*** has been responsible for developing selected options to meet the agreed objectives and design criteria set for the Tideway. The work has represented a major part of the overall development work.
A design brief was developed for the two main Tideway Tunnel options and clarification of any additional work requested. The impact on the treatment requirements has also been assessed, linked to the proposed mode of operation and the planned AMP4/5 upgrades to the Tideway STWs. The requirements for any additional sludge treatment and disposal has also been assessed.

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

The output from this group has been scoped and costed solutions with outline programmes for implementation. This includes an assessment, working closely with the Planning and Environment group, of the likely planning and environmental requirements.

The scope of the development work has been considered 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 6m tunnel to be considered.

Option 2: This option is put forward as a partial solution. It comprises two shorter tunnels, in west and east London, to intercept intermittent discharges along these stretches of the river, and with treatment in East London.

An initial piece of work was carried out to define the required outputs and design criteria. A short list the sub-options was then developed and reviewed resulting in three sub options for 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 Tideway Operating Agreement standards. 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 that have already been approved. Options have been reviewed 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 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 been provided to also allow 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 are:

(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 has also been assessed.

Implementation Programme – Programmes have been developed for the delivery and full implementation of the alternative options and sub-options. Identified phasing options will also be evaluated.

Issues & Risks – Issues and risks associated with alternative options have been assessed including planning, environmental, engineering and cost estimates for construction and operation. Odour has been looked at as a particular risk item.

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

2 OPTIONS DESCRIPTION

2.1 INTRODUCTION

This section addresses the scope and intended operation of the various options under consideration.

The options under consideration are based on the storage tunnel concept proposed by TTSS as the recommended option. This concept has been further developed as part of this study. The general developments, applicable to each option, are discussed below. This is followed by a section on each option describing the scope, intended operation and assumptions specific to each. For each option there are potential sub-options for early implementation of a phase of the works. As all options incorporate the interception of Combined Sewer Overflows (CSOs) the categorisation of the CSOs is summarised below.

The assessment of each option/variant including estimated cost, programme for implementation and interception performance is detailed in Detailed Option Assessment.

The two main options, each with three variants are listed in the table below:

Option	Description
1a	Full-length Storage Tunnel – 7.2m Diameter
1b	Full-length Storage Tunnel – 6.0m Diameter
1c	Full-length Storage Tunnel – 7.2m Diameter, tunnels joining at Beckton
2a	West Tunnel 7.6m Diameter & East Tunnel 13m Diameter
2b	West Tunnel 7.6m Diameter & East Tunnel 10m Diameter, with Additional Treatment Capacity
2c	West Tunnel 7.6m Diameter & East Tunnel (via Charlton) 10m Diameter

2.2 CATEGORISATION OF THE CSOS

The CSOs were categorised according to environmental impact and frequency of operation as described below.

Category	Description
1	CSOs that operate frequently and have an adverse environmental impact
2	CSOs that do not operate frequently but have an adverse environmental impact
3	CSOs which have no significant environmental impact
4	CSOs that operate frequently but do not have an adverse environmental impact

This lead to the following categorisation and the proposal to intercept only category 1 and 2 CSOs:

Category 1	Category 2	Category 3	Category 4
Acton	Stamford Brook	LL1 Brook Green	London Br
W Putney	N W Relief	Falconbrook Relief	Isle of Dogs P/S
Hammersmith P/S	Wick Lane	Horseferry	Canning Town P/S
Putney Bridge	Church St	Wood St	
Frogmore	Queen St	Goswell St	
Jews Row	Smith St	Pauls Pier	
Falconbrook P/S	KSP	Battle Br	
Lots Rd P/S	Grosvenor	Beer Lane	
Ranelagh	Savoy St	Iron Gate	
Western P/S	Norfolk St	Nightingale	
S W Relief	Essex St	Union Wharf	
Heathwall P/S		Wapping Dock	
Clapham		Cole Stairs	
Brixton		Bell Wharf	
Regent St		Ratcliffe	
Northumberland St		Blackwall Sewer	
Fleet		Henley Rd	
N E Relief		Store Rd	
Deptford			
Greenwich P/S			
Abbey Mills P/S			
Charlton			
Holloway			
Shad Thames P/S			
Earl P/S			
Total: 25	**Total: 11**	**Total: 18**	**Total: 3**

Although it is a category 3 CSO the Falconbrook Relief will also be intercepted as its discharge point is immediately adjacent to the Jews Row Outlet. Frogmore CSO consists of two outlets to the River Wandle, just upstream of the confluence with the Thames. Initially it was thought that interception of the downstream outlet would be sufficient to capture the overflow. However more detailed investigation has shown that the existing relief sewer between the two Frogmore outlets is unlikely to have sufficient hydraulic capacity to transfer flows downstream to reduce discharge from the upstream outlet. Therefore an additional interception chamber, shaft and length of tunnel are required to complete the interception. This additional works is now included in the scope of works for each relevant option.

Many of the Category 3 CSOs are blocked or are no longer used. Of those that remain several serve only local sewers and therefore operate very infrequently with small volumes of discharge. It is considered uneconomic to incur the cost of the interceptions works for such little benefit.

2.3 CSO Interception Works

Generally it is proposed to intercept the flows close to the outfall for each CSO. This ensures that there are no downstream connections from the sewerage system which would still discharge. The interception works typically consist of an underground interception chamber constructed adjacent to the existing CSO structure or outfall conduit, together with a drop shaft and interconnecting tunnel to the main storage tunnel.

The CSO interception works were subject to a thorough study and reported in the Supplementary Report to Government November 2005. This work has been reviewed as part of this study and the full scope included in the budget estimates.

2.4 TREATMENT PROPOSALS

The Thames Tideway Strategic Study (TTSS) reports and Supplementary Report to Government recommendations included for the storage tunnel to be pumped out for treatment in a dedicated storm water treatment facility at Crossness before being discharged to the Tideway and for supplementary pump-out and treatment at Beckton STW when capacity is available. The proposed dedicated treatment facilities at Crossness included Preliminary Treatment followed by Deep Bed Filtration. The tunnel pump-out rate at Crossness was assumed to be approximately 10m^3/s.

The principle modification to this concept is the proposal to terminate the main tunnel at Beckton STW and to pump-out the tunnel draindown flow to full treatment. Beckton STW would be extended in capacity to receive and treat this additional flow. The reasons for this modification are discussed below.

The interception of the CSOs to the proposed storage tunnel is only one element of the works required to enable water quality in the Tideway to meet the desired objectives. The other elements include major upgrades to the treatment capacity provided at Beckton, Crossness and Mogden works. These are being implemented during AMP4 and AMP5. These improvements will both increase the amount of flow to be treated at each works and augment the existing treatment process to enable the treated effluent to meet tighter consents.

Contrary to the assumptions made at the time of completion of the TTSS final report, it is now evident that all flows pumped from the tunnel will be required to meet the same effluent quality criteria as are set out in the new consents for each works. Therefore a further increase in treatment capacity over and above that being implemented during AMP4/5 would be required to facilitate treatment of the draindown flow from the tunnel. Hence an increased area of land at both Beckton and Crossness would have been required to accommodate these treatment extensions to the works.

While the TTSS report proposed construction of dedicated facilities, based on physical methods of treatment, for the tunnel drain-down flows, the requirement for treated effluent from the tunnel treatment facilities to achieve the same consent as the main works requires secondary treatment and therefore militates against construction of a separate works. To maintain operation of the secondary treatment facilities the tunnel draindown flows must be treated in a further extension of the works in addition to the upgrades to be implemented for AMP4/5.

At Crossness the land owned by Thames Water includes:

- The current Operational Site, inclusive of the conservation area which surrounds the historic Beam Engine House,
- The Crossness Nature Reserve, which occupies land to the east of the Operational Site and was designated as a nature reserve in response to a S.106 planning condition relating to construction of the Crossness Sludge Powered Generator (SPG),
- The Crossness Southern Marshes, which separate the A2016 road from the proposed East Thamesmead Business Park.

Except for the developed area of the existing works, these areas are all designated as Metropolitan Open Land and Areas of Metropolitan Importance for Nature Conservation.

Discussions with key stakeholders during development of designs for the AMP4/5 extensions at Crossness have indicated that there will be strong opposition to extension of the STW on any land outside the boundary of the current Operational Site.

As an alternative to treatment of tunnel flows at Crossness, consideration has also been given to drain-down and treatment of the tunnel flows at Beckton STW, where space for expansion is available within the land owned by Thames Water. Beckton STW is also the subject of a planned AMP4/5 upgrade to meet the same consent criteria as apply at Crossness.

After review of the merits of development of new treatment facilities to handle flows from the tideway tunnel at both Beckton and Crossness, it is now proposed that these should be provided only at Beckton for the following reasons:

- Both works are to be upgraded in AMP4/5 and hence similar economies of scale will apply to construction work at either site.
- Planning objections are likely to be raised for both sites if development of additional treatment capacity requires the new works to be outside the boundary of the current Operational Sites.
- The same consent will apply to effluent quality at Beckton as at Crossness and flow rates for pump-out from the tunnel will be identical. However construction of new facilities at Beckton would be less expensive due to spare capacity that currently exists in the inlet works and primary sedimentation tanks.
- As compared to a tunnel which terminated at Crossness, construction of facilities for tunnel drain-down and treatment at Beckton will save the considerable costs associated with approximately 4.1 km of 7.2 m diameter tunnel and a pump-out 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.

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

2.5 Treatment and Pump-out Capacity

The notional flow to full treatment (FFT) is determined by the sum of the average maximum draindown rate (when the tunnel is completely filled) and the average flow to the works projected to 2021 (1527Mld).

The maximum average pump capacity for each option/variant is based on draining the full tunnel storage volume in 48hours. Not all events will completely fill the tunnel, therefore there are potential options for the draindown operation, briefly outlined as follows:

1. Reduce rate of draindown utilizing the variable speed capability of the pumping installation so that the part-filled volume is still cleared in 48hours. This would spread the load on the works but maintains the duration of higher flow (but less than maximum capacity), this may improve effluent quality to help assure river quality objectives. However if an event, large enough to just fill the tunnel, occurs soon after a previous smaller event there is a potential risk of creating an additional bypass of small volume as the tunnel would not be completely empty.
2. Draindown could be limited to night-time to reduce energy costs. This could be advantageous if supply is from the grid. It may also make better utilization of treatment capacity as night-time flows to the works are generally lower. However duration of draindown would be extended and could suffer the same risk as above
3. Draindown at maximum rate, irrespective of volume captured to clear tunnel as fast as possible. This avoids the potential risk of additional bypass as a result of back-to-back events but maintains the maximum hydraulic flow rate to the works, albeit for a shorter duration. Effluent quality will reduce with time during draindown at maximum capacity.

Because of the potential risk of creating unnecessary bypass, the first two options for draindown operation are not recommended. Therefore draindown at the maximum rate is assumed.

Because of diurnal variation of flow to the works the actual draindown rate will be varied to match the available treatment capacity, being the difference between FFT and the actual inflow to the works as it varies throughout the day. When inflow to the works is high the draindown rate will be reduced and conversely when flow to the works is low the draindown rate will be increased. In order to achieve the average maximum draindown rate the peak capacity of the pumping plant will need to be higher than the average maximum draindown rate.

The pumping plant duties for each option is described for each option and variant in the scope for each option below.

2.6 MAIN PUMP-OUT SHAFT

The option recommended by TTSS - A (ref) - was based on two pump-out shafts, the main one to storm treatment plant at Crossness STW and a secondary pump-out to full treatment at Beckton STW. This arrangement included significant standby capacity for the pumping plant as well as treatment capacity. Therefore the pumping plant in each shaft could be based on the peak capacity only.

As the full tunnel options and eastern section of the partial tunnel option include for only one pump-out shaft to Beckton STW, additional pumping plant is therefore required to provide standby capacity. The pump-out shaft therefore needs to be bigger to accommodate this additional plant.

2.7 ABBEY MILLS TRANSFER

During the current development of these options and their variants, most of the early implementation options required an overflow tunnel at Beckton to prevent the discharge of CSO flow from Abbey Mills to the River Lee. Elimination of these discharges to the River Lee is considered a significant improvement to the environment, particularly in the light of the proposed Olympic Park and regeneration proposals for the Lower Lee Valley. If completion to the full scheme then re-introduced discharge to the River Lee from Abbey Mills, this would have been perceived as a significant retrograde step.

Therefore the facility for transfer of Abbey Mills CSO flows and bypass to the River Thames at Beckton when the capacity of the tunnel system is exceeded is considered for all options. The required scope and operation for this facility is described in the scope for each option.

In general this bypass would be affected by pumping flows into the interception shaft at Abbey Mills utilising the existing Station F pumping station to increase head and surcharge the tunnel, so that the flow is forced through the storage tunnel and bypass tunnel to discharge via an overflow structure into the existing Beckton STW outfall channel.

It is proposed that the overflow structure incorporates a weir to protect the bypass tunnel, and therefore the whole tunnel system, against inundation from the river at high tide. The highest astronomical tide is approximately 4.39mAOD, whereas the predicted 1 in 2 year and 1 in 10 year tidal events are 4.50mAOD and 5.25mAOD respectively. Therefore a fixed weir crest level of 5.00mAOD is considered to provide an adequate level of protection without incurring excessive restriction of hydraulic capacity. The bypass would operate satisfactorily during these tidal events if required.

For the rarer tidal events the predicted levels are higher. Including climate change to 2052, the predicted 1 in 100 year tidal event is 5.83mAOD and the 1 in 1000 year tidal event is 6.31mAOD. To protect the tunnel system against these rare events the overflow structure would also include river flaps to prevent, or significantly limit, back flow. These rare tidal events would reduce the hydraulic transfer capacity of the bypass. However in order to do so these tidal events would have to occur at the same time as a bypass event, the combination of which would be even more unlikely.

For the full tunnel options, it will be necessary to isolate the section of tunnel providing this transfer facility from the rest of the tunnel to prevent surcharge of upstream CSOs. This will require the operation of isolating penstocks during the filling cycle. Further isolation at the

Charlton Shaft to prevent backflow through the Charlton CSO would also be necessary for the partial tunnel options and some phases implemented early. The detail of these isolation measures is specific to each option and discussed in the scope.

The potential transfer capacity, implications of tunnel surcharge and operational risk associated with each option are discussed in Detailed Option Assessment.

2.8 Operation

The operation of the tunnel options will be intermittent, depending on the frequency and duration of rainfall events, but each period of use will involve a cycle of four stages:

1. Filling,
2. Standing part full or full awaiting commencement of drain-down pumping,
3. Drain-down,
4. Standing empty awaiting the next heavy rainfall event.

2.8.1 Filling

All of the 36 category 1 and 2 CSOs can be intercepted by the full tunnel options, whereas for the partial tunnel options the west tunnel intercepts 17 CSOs and the East tunnel intercepts Abbey Mills as described in the scope for each option. The east tunnel of option 2c would also intercept the Charlton CSO.

During a rainfall event, which will vary spatially and temporally, the excess flows from those connected CSOs that spill will be intercepted and passed via the connection chamber, drop shaft and interconnecting tunnel to the main tunnel itself. Where the incoming flow enters the tunnel could be very variable, however the accumulated flow will follow the grade and pass to the downstream end of the tunnel.

The tunnel will begin to fill and air will be displaced. The main tunnel has sufficient capacity to pass large quantities of accumulated flow whilst maintaining an air gap above the free surface to allow air to be freely displaced via the ventilation grilles at the main shaft sites. Eventually the tunnel will fill sufficiently such that, sequentially, one by one, the main shafts will become water-locked from the main tunnel. Progressively therefore more air will tend to be displaced from the upstream main shafts as the tunnel fills.

Displaced air during filling may potentially create odour, however this potential is mitigated in several ways:

1. Preceding filling, the air in the tunnel would have been continuously changed by natural or forced ventilation to ensure low odour levels.
2. During filling, the storm flows will be relatively fresh with little opportunity for malodours to develop.
3. The method of interception, incorporating cascades in the drop shafts will tend to aerate the storm flow delaying the onset of septicity.
4. The evacuation of displaced air will be controlled by the ventilation system with exhaust gases being passed to odour control plant for as long as possible until overwhelmed by the rate of displacement.
5. The displacement of air from the tunnel will occur over a relatively short time, therefore if there is any residual odour it will be dispersed quickly.
6. Large volumes of displaced air will only occur a few times a year as a result of large events.

The vast majority of events will only part fill the tunnel. If, however, a rainfall event produces sufficient CSO flow the tunnel will completely fill. At this stage any further excess CSO flow will be passed to the river via the existing CSO outfalls. The principle exception to this being the Abbey Mills flows, where it is intended to transfer these flows to discharge to The River Thames at Beckton, as described in Abbey Mills Transfer.

2.8.2 Standing part full or full awaiting commencement of drain-down pumping,

At the end of an event the CSOs will stop passing flow to the main tunnel. There will be a period of a few hours before draindown when the accumulated flow is stationary. Solid matter in the flow will tend to settle. However there will be no displaced air from the tunnel as there would be no flow and therefore low likelihood of release of odour. For the full tunnel options, the flushing penstock gates would be closed during this period in anticipation of sequential emptying of the tunnel lengths.

At this stage potential odour could only be released from the free surface of the stored flow. The tunnel would still be vented by either forced or natural ventilation. If the tunnel were only partly full with an air gap above the stored flow it would be vented via those main shafts that are not water-locked or isolated from the main tunnel by the depth of the stored flow. Where shafts are water-locked the ventilation system would vent that main shaft only.

2.8.3 Drain-down

Once flow to the treatment works begins to reduce to normal levels, the main pumps will be switched on to start the draindown operation. This operation will vary in detail between the various options, in particular there are fundamental differences between the full and partial tunnel options. The specific draindown operation is described within the scope for each option, however there are general issues as discussed below.

The pumping rate for draindown will be limited by the capacity of the treatment works to receive flow. The pumping plant will be variable speed to accommodate the diurnal change in available capacity as detailed in Pump-Out Capacity. Therefore the general horizontal velocity of the flow will be low and tend not to re-suspend larger and more dense solids. Sequential emptying of the lengths of the full tunnel options will generate intermittent high flows to flush through this solid deposition. However this is less likely to occur with single lengths of tunnel.

It is therefore proposed that the most upstream shaft of any single length of tunnel incorporates a full height wall with isolating penstock to capture storm overflow or to store flow abstracted from the river to facilitate flushing of the tunnel by rapid release of this accumulated flow.

Draindown of the tunnel system will tend to draw air in thus minimising the potential for release of odour during this stage.

2.8.4 Standing empty awaiting the next heavy rainfall event.

Following draindown and flushing the tunnel will remain empty awaiting the next event. There is potential for some solid deposition to remain in the invert of the tunnel and for sliming of the sides which may generate some odour. Therefore the tunnel will be continuously vented during this stage either by natural or forced ventilation to ensure that odour does not build up to noticeable levels. Dispersion of exhaust gases via vent stacks or odour control plant will considerable aid dispersion and further reduces the odour intensity.

2.9 VENTILATION AND ODOUR CONTROL

Due to the length and depth of the tunnel legs it is not feasible to achieve ventilation rates significantly greater than 1 air change per day when the tunnel is standing empty. Natural ventilation could provide this level of ventilation for a portion of the time, however forced ventilation will be needed for at least some of the time and may be needed to control from which shaft(s) air is released from the tunnel. Forced ventilation will be required for air exhausted to odour control plant.

A combined natural and forced ventilation system is proposed. This system uses natural ventilation when possible and forced ventilation when necessary. The provision for natural ventilation, requiring larger vent areas, does not represent additional cost as it uses the provision required to release displaced air on filling.

Because of health and safety requirements ventilation of the tunnel for access for maintenance and inspection will require a higher rate of air changes. It is not practical or economic to provide permanent plant for such intermittent use. It is therefore proposed that, to effect a manned entry, temporary plant is hired in to accommodate this use. Typical tunnel construction fans and portable generators would form the core of this temporary ventilation plant requirements.

2.10 Control of Flows to the Treatment Works

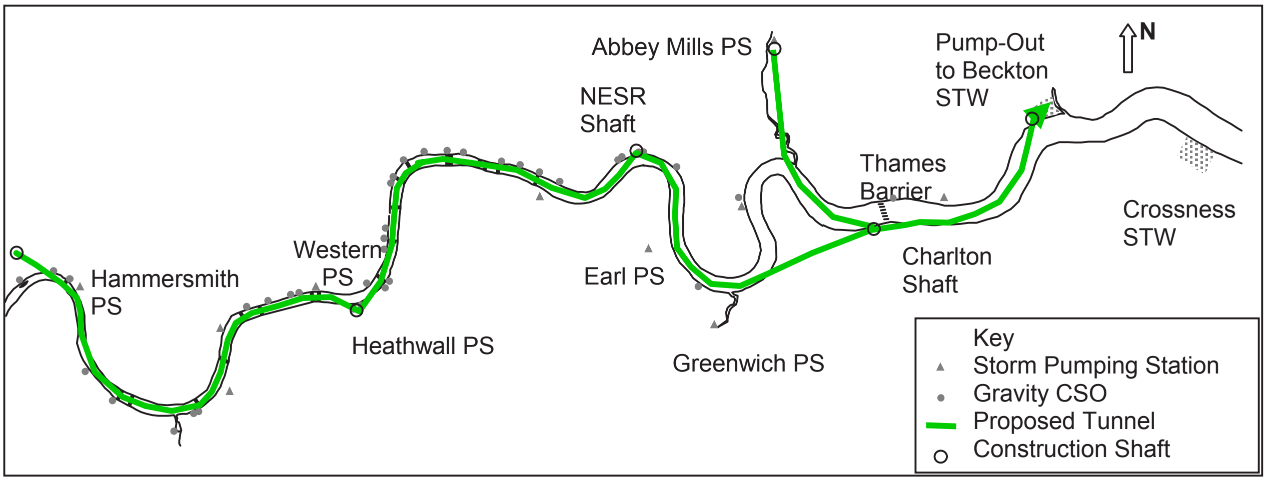
During dry weather, flows from the High and Mid Level Interceptor Sewers pass by gravity to the Northern Outfall Sewer (NOS) at Wick Lane, whereas flows from the Low Level Sewers are pumped to the NOS by Station F at Abbey Mills for transfer to Beckton STW. During a rainfall event, when the current maximum capacity of Beckton STW is reached, all flow arriving at Abbey Mills via the Low Level Sewers is isolated from the NOS and pumped directly to the river.

As all options require an upgrade of the treatment capacity to treat tunnel draindown flows at Beckton STW it will therefore be able to receive more flow during a rainfall event. It is therefore proposed to fully utilise this additional treatment capacity and maintain the maximum flow to the upgraded plant at Beckton STW via the Northern Outfall Sewer. This represents a significant change to the current operation of Abbey Mills during wet weather.

In order to maintain the maximum flow through the NOS and take advantage of the proposed higher treatment capacity, the output from Station F will need to be controlled so that a proportion of this flow can be directed to the NOS. The remaining proportion will be intercepted to the tunnel. This action will optimise the interception of Abbey Mills CSO flows to the tunnel.

However there may be few events, which by virtue of their spatial and temporal distribution it may not be possible to direct the maximum flow to the works via the NOS. For the full tunnel options this may occur when a moderately large event impacts on the west of the catchment. For this type of event flows in the NOS would tend not to increase significantly. For these events it may be necessary to supplement flows to the works by pump-out from the tunnel during the event to make full use of the maximum treatment capacity

2.11 Option 1A



2.11.1 Scope of Tunnel and shaft works

Main Tunnel: 32.2km @ 7.2m diameter tunnel
Abbey Mills Link: 5km @ 7.2m diameter
Construction shafts: 5nr
Total Storage Volume: 1,618,000m^3
Pump-Out Shaft at Beckton STW
Overflow Shaft at Beckton STW
Bypass Tunnel: 1.3km @5m diameter with construction shaft and overflow structure

2.11.2 Scope of CSO interception works

All Category 1 and 2 CSOs intercepted
CSOs Intercepted: 36nr

2.11.3 Scope of Treatment plant

The maximum average draindown rate is 809Mld, therefore the required notional Full Treatment rate is 2,336Mld

2.11.4 Scope of Pumping and Power Plant

The maximum average draindown rate of 809Mld is equivalent to 9.36m^3/s. In order to achieve this average rate the peak capacity required is 12.20m^3/s. The envisaged pumping plant consists of 6 units (4 duty, 2 standby) each capable of 3.05m^3/s, approximate head of 85m giving a nominal power rating of 3.5Mw. The maximum power requirement with all duty pumps running would be approximately 14Mw.

2.11.5 Draindown and Flushing

The draindown and flushing cycle for this tunnel would be generally as described before. To facilitate sequential emptying and therefore flushing of the individual tunnel lengths, the main shafts at Heathwall and NESR would incorporate in-line penstocks, the main shaft at Charlton would incorporate a penstock for the main tunnel leg and the leg to Abbey Mills. The most upstream shaft at Homefield would include a full height division wall and penstock to retain either storm flow or water abstracted from the river for subsequent release for flushing. The Abbey Mills shaft would incorporate a similar full height division wall and penstock but would only retain storm flow for flushing.

During filling the penstocks at Abbey Mills and Homefield would be closed, whereas the other penstocks will be open to allow full distribution of intercepted flow to storage. At the start of the draindown and flushing cycle all penstocks would be closed and the following sequence followed:

1. Start pump-out and draindown the Charlton to Beckton tunnel leg

2. Open the penstock at Charlton for the tunnel leg to Abbey Mills. This leg will empty quite rapidly into the empty Charlton to Beckton leg, generating flow velocities to re-suspend deposition in both legs. Continue pump-out to draindown.
3. Open the penstock at Charlton on the main tunnel to empty the tunnel leg between NESR and Charlton. This leg will again empty quite rapidly into the empty Charlton to Beckton leg. Continue pump-out to draindown.
4. Open the penstock at NESR on the main tunnel to empty the tunnel leg between NESR and Heathwall, emptying this leg rapidly downstream. Continue pump-out to draindown.
5. Open the penstock at Heathwall on the main tunnel to empty the tunnel leg between Heathwall and Homefield. This final leg will again empty quite rapidlydownstream. Continue pump-out to draindown.
6. Open the penstock at the Abbey Mills shaft to release the stored storm water as a final flush for this tunnel leg. Continue pump-out to draindown.
7. Open the penstock at the Homefield shaft to release the stored storm water (or abstracted river water) as a final flush for the main tunnel. Continue pump-out to draindown
8. Repeat operation 7, with abstracted river water, if necessary

2.11.6 Ventilation and Odour Control

The ventilation and odour control system would consist of ventilation intakes at Homefield, NESR and Charlton, with exhausts at Heathwall, Beckton and Abbey Mills. The exhaust sites could include chemical odour control plant if necessary before discharge via approximately 10m high exhaust stacks to aid dispersion.

2.11.7 Abbey Mills Transfer

Most events will not completely fill the tunnel creating a bypass to the river. This operational intervention is only necessary when the tunnel completely fills and Abbey Mills is still required to discharge. As the system nears full capacity, level monitors in the main shafts will indicate a more rapid increase in level as the tunnel itself is full and the only remaining storage is in the main shafts. At this point the penstock on the main tunnel in the shaft at Charlton is closed to isolate the upstream section of the main tunnel, the Charlton CSO connection would also be isolated.

Should the upstream CSOs continue to discharge then, once the upstream shafts are completely full, bypass to the river will occur via the existing outlets. With the penstock at Charlton closed the tunnel legs from Abbey Mills to Charlton to Beckton can then operate as a transfer conduit for Abbey Mills CSO flows direct to Beckton. This isolated conduit would continue to fill, eventually the level in the shaft at Abbey Mills would increase, restricting discharge from the suction culvert of Station F to the tunnel system. The penstock on the suction culvert would then be closed and the penstock on the connection between the outlet culvert and the Abbey Mills shaft opened.

The level would continue to rise automatically starting Station F pumps, which would then force flow into the tunnel, surcharging it sufficiently to push flow through the isolated tunnel legs to Beckton and then via the overflow tunnel from the Beckton Overflow Shaft to discharge to the main outfall culvert.

2.11.8 Potential Early Implementation

There are two potential options for early implementation of the eastern section of the tunnel system which would facilitate interception of Abbey Mills CSO flows, to storage and transfer to discharge to the River Thames. The interception performance for these phased options depends upon peak flows for transfer and is discussed in Detailed Options Assessment.

1. Abbey Mills to Charlton (at 7.2m diameter), discharge to R Thames at Charlton
2. Abbey Mills to Charlton (at 7.2m diameter) and Charlton to Beckton (at 7.2m diameter), discharge to River Thames at Beckton

The first option for early implementation utilises the existing Station F pumps at Abbey Mills to surcharge the tunnel and force flow through. This would enable significant CSO flows from Abbey Mills to be transferred to Charlton for discharge direct to the River Thames.

As the tunnel would be an inverted siphon flow will accumulate, which would be pumped out to the river. There are no treatment implications associated with this phased option as there is no additional flow passed to the treatment works.

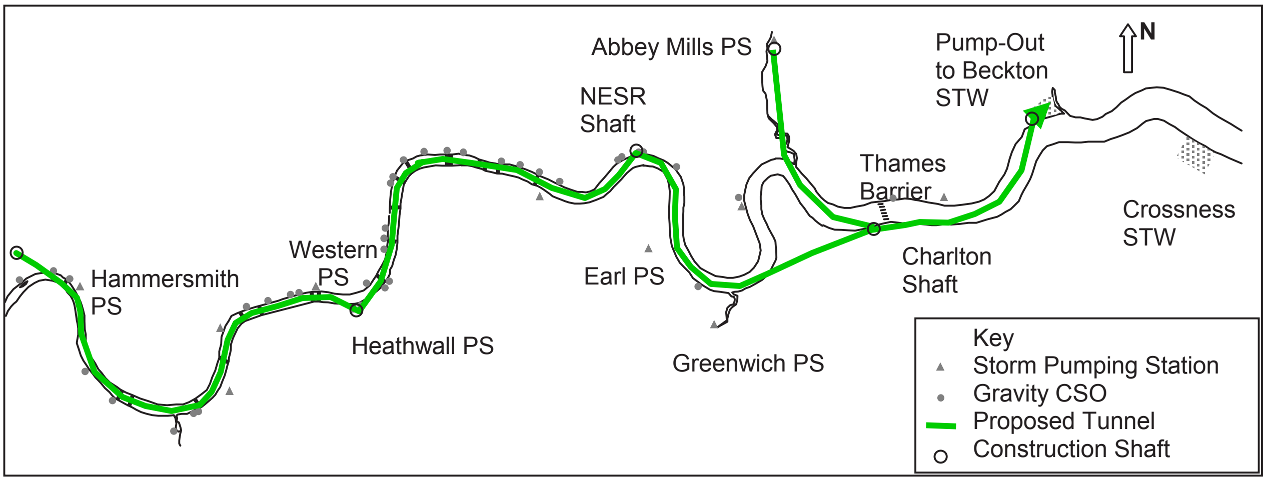
The second option for early implementation would operate in a similar fashion, however Abbey Mills flows would be transferred for discharge to the River Thames at Beckton. It would be possible to connect the Charlton CSO to the main shaft at Charlton, however for such an interim application this is unlikely to be beneficial as the Charlton CSO would have to be isolated from the main shaft to prevent backflow through this connection whenever the tunnel surcharges with flow from Abbey Mills. This will occur for virtually every event as Abbey Mills CSO flows are greater and more frequent.

As this potential option for early implementation terminates at Beckton it will be possible to drain the accumulated flow in the tunnel system to treatment. Assuming a draindown period of 48hours this would result in a maximum average draindown rate of 2.43m^3/s or 210Mld. For this duration the flow to the works will be increased above the average flow as follows:

Year	Average Flow (Mld)	Notional Maximum Full Treatment (Mld)
2006	1344	1554
2016	1467	1677
2021	1527	1737

These maximum flows are within the full treatment rates proposed for the AMP4/5 upgrade for Beckton.

2.12 Option 1B



2.12.1 Scope of Tunnel and Shaft Works

Main Tunnel: 32.2km 6.0m diameter tunnel
Abbey Mills Link: 5km 6.0m diameter
Construction shafts: 5nr
Total Storage Volume: 1,155,000m^3
Pump-Out Shaft at Beckton STW
Overflow Shaft at Beckton STW
Bypass Tunnel: 1.3km @5m diameter with construction shaft and overflow structure

2.12.2 Scope of CSO interception works

All Category 1 and 2 CSOs intercepted
CSOs Intercepted: 36nr

2.12.3 Scope of Treatment plant

The maximum average draindown rate is 578Mld, therefore the required notional Full Treatment rate is 2,105Mld

2.12.4 Scope of Pumping and Power Plant

The maximum average draindown rate of 578Mld is equivalent to 6.69m^3/s. In order to achieve this average rate the peak capacity required is 9.60m^3/s. The envisaged pumping plant consists of 6 units (4 duty, 2 standby) each capable of 2.40m^3/s, approximate head of 85m giving a nominal power rating of 2.8Mw. The maximum power requirement with all duty pumps running would be approximately 11.2Mw.

2.12.5 Draindown and Flushing

The draindown and flushing cycle for this tunnel would be as described for Option 1a.

2.12.6 Ventilation and Odour Control

The ventilation and odour control system would consist of ventilation intakes at Homefield, NESR and Charlton, with exhausts at Heathwall, Beckton and Abbey Mills. The exhaust sites could include chemical odour control plant if necessary before discharge via exhaust stacks approximately 10m high to aid dispersion.

2.12.7 Abbey Mills Transfer

The operational intervention required for the transfer of Abbey Mills flows would be as described for Option 1a. However as the tunnel legs are only 6m in diameter the maximum transfer rate is likely to be insufficient for peak flows from Abbey Mills.

2.12.8 Potential Early Implementation

There are two potential options for early implementation of the eastern section of the tunnel system which would facilitate interception of Abbey Mills CSO flows, to storage and transfer to discharge to the River Thames. The interception performance for these phased options depends upon peak flows for transfer and is discussed in Detailed Options Assessment.

1. Abbey Mills to Charlton (at 6.0m diameter), discharge to R Thames at Charlton
2. Abbey Mills to Charlton (at 6.0m diameter) and Charlton to Beckton (at 6.0m diameter), discharge to River Thames at Beckton

The operation of these potential options for early implementation would be similar to that described for Option 1a, however their hydraulic capacity would be significantly reduced.

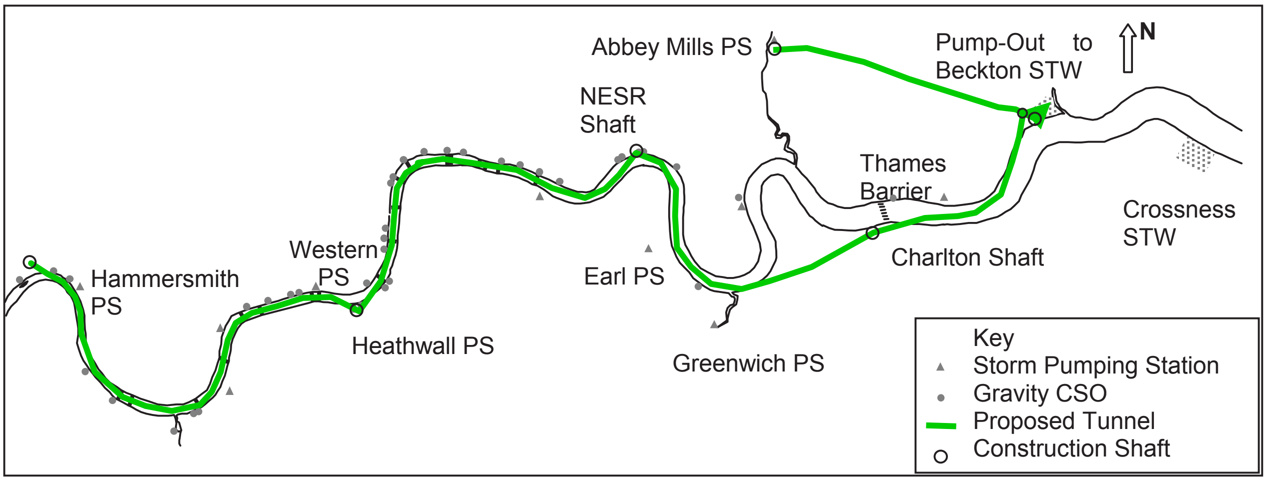
There are no treatment implications associated with the first option as accumulated flows would be pumped out to the river and there would be no additional flow passed to the treatment works.

The second option terminates at Beckton, therefore the accumulated flow could be pumped out to treatment. Assuming a draindown period of 48hours this would result in a maximum average draindown rate of 1.78m^3/s or 154Mld. For this duration the flow to the works will be increased above the average flow as follows:

Year	Average Flow (Mld)	Notional Maximum Full Treatment (Mld)
2006	1,344	1,498
2016	1,467	1,621
2021	1,527	1,681

These maximum flows are within the full treatment rates proposed for the AMP4/5 upgrade for Beckton.

2.13 Option 1c



2.13.1 Scope of Tunnel and shaft works

Main Tunnel: 32.2km @ 7.2m diameter tunnel
Abbey Mills Link: 5.5km @ 7.2m diameter
Construction shafts: 5nr
Total Storage Volume: 1,638,000m^3
Pump-Out Shaft at Beckton STW
Overflow Shaft at Beckton STW
Bypass Tunnel: 1.3km @5m diameter with construction shaft and overflow structure

2.13.2 Scope of CSO interception works

All Category 1 and 2 CSOs intercepted
CSOs Intercepted: 36nr

2.13.3 Scope of Treatment plant

The total storage volume only approximately 1% more than Option 1a, therefore the same values have been taken for consistency. The maximum average draindown rate is 809Mld, therefore the required notional Full Treatment rate is 2,336Mld

2.13.4 Scope of Pumping and Power Plant

The maximum average draindown rate of 809Mld is equivalent to 9.36m^3/s. In order to achieve this average rate the peak capacity required is 12.20m^3/s. The envisaged pumping plant consists of 6 units (4 duty, 2 standby) each capable of 3.05m^3/s, approximate head of 85m giving a nominal power rating of 3.5Mw. The maximum power requirement with all duty pumps running would be approximately 14Mw

2.13.5 Draindown and Flushing

The draindown and flushing cycle for this tunnel would be generally as described before for Option 1a, but the provision of penstocks and sequence will be slightly different. To facilitate sequential emptying and therefore flushing of the individual tunnel lengths, the main shafts at Heathwall, NESR and Charlton would incorporate in-line penstocks. The Beckton Overflow Shaft would incorporate a penstock for the main tunnel leg and the leg to Abbey Mills. The most upstream shaft at Homefield would include a full height division wall and penstock to retain either storm flow or water abstracted from the river for subsequent release for flushing. The division wall would also incorporate a high-level overflow weir to limit the depth of stored flow in the shaft. The Abbey Mills shaft would incorporate a similar full height division wall, with high level overflow weir and penstock but would only retain storm flow for flushing.

During filling the penstocks at Abbey Mills and Homefield would be closed, whereas the other penstocks will be open to allow full distribution of intercepted flow to storage. At the start of the draindown and flushing cycle all penstocks, except the penstock on the main tunnel in the Beckton Overflow Shaft, would be closed and the following sequence followed:

1. Start pump-out and draindown the Charlton to Beckton tunnel leg
2. Open the penstock in the Beckton Overflow Shaft for the tunnel leg to Abbey Mills. This leg will empty quite rapidly into the empty Charlton to Beckton leg, generating flow velocities to re-suspend deposition in the Abbey Mills leg. Continue pump-out to draindown. The backflow into the Charlton leg may leave some deposition after emptying this stage, but this will be removed by subsequent stages.
3. Close the penstock for the tunnel leg to Abbey Mills to prevent backflow and open the penstock at Charlton on the main tunnel to empty the tunnel leg between NESR and Charlton. This leg will again empty quite rapidly into the empty Charlton to Beckton leg, re-suspending any deposition brought about from backflow from flushing the Abbey Mills leg. Continue pump-out to draindown.
4. Open the penstock at NESR on the main tunnel to empty the tunnel leg between NESR and Heathwall, emptying this leg rapidly downstream. Continue pump-out to draindown.
5. Open the penstock at Heathwall on the main tunnel to empty the tunnel leg between Heathwall and Homefield. This final leg will again empty quite rapidly downstream. Continue pump-out to draindown.
6. Open the penstock for the tunnel leg to Abbey Mills and open the penstock at the Abbey Mills shaft to release the stored storm water as a final flush for this tunnel leg. Continue pump-out to draindown.
7. Open the penstock at the Homefield shaft to release the stored storm water (or abstracted river water) as a final flush for the main tunnel. Continue pump-out to draindown
8. Repeat operation 7, with abstracted river water, if necessary

2.13.6 Ventilation and Odour Control

The ventilation and odour control system would consist of ventilation intakes at Homefield, NESR, Charlton and Abbey Mills, with exhausts at Heathwall and Beckton and Abbey Mills. The exhaust sites could include chemical odour control plant if necessary before discharge via exhaust stacks approximately 10m high to aid dispersion.

2.13.7 Abbey Mills Transfer

Most events will not completely fill the tunnel creating a bypass to the river. This operational intervention is only necessary when the tunnel completely fills and Abbey Mills is still required to discharge. As the system nears full capacity, level monitors in the main shafts will indicate a more rapid increase in level as the tunnel itself is full and the only remaining storage is in the main shafts. At this point the penstock on the Beckton Overflow Shaft is closed to isolate the upstream section of the main tunnel.

Should the upstream CSOs continue to discharge then, once the upstream shafts are completely full, bypass to the river will occur via the existing CSO outlets. With the penstock in the Beckton Overflow Shaft closed the tunnel leg from Abbey Mills to Beckton can then operate as a transfer conduit for Abbey Mills CSO flows direct to Beckton. This isolated conduit would continue to fill, eventually the level in the shaft at Abbey Mills would increase, restricting discharge from the suction culvert of Station F to the tunnel system. The penstock on the suction culvert would then be closed and the penstock on the connection between the outlet culvert and the Abbey Mills shaft opened.

The level would continue to rise automatically starting Station F pumps, which would then force flow into the tunnel, surcharging it sufficiently to push flow through the isolated tunnel kegs to Beckton and then via the overflow tunnel from Beckton Overflow Shaft to discharge to the main outfall culvert.

2.13.8 Potential Early Implementation

There is one potential option for early implementation of the eastern section of the tunnel system, namely the Abbey Mills to Beckton leg at 7.2m diameter, to storage and transfer to discharge to the River Thames. The interception performance for this phased option depends upon peak flows for transfer and is discussed in Detailed Options Assessment

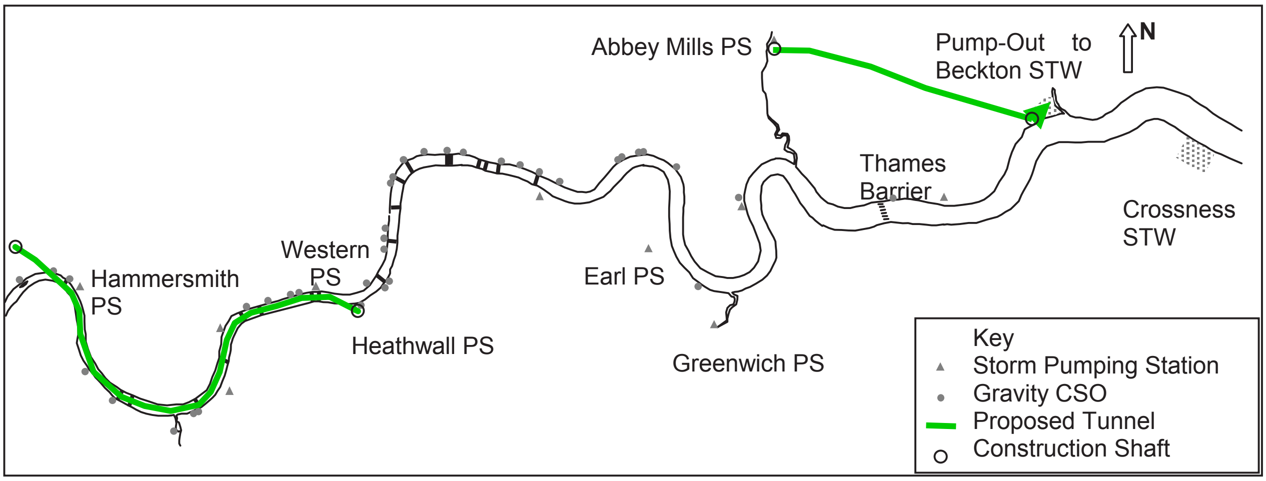
This option for early implementation utilises the existing Station F pumps at Abbey Mills to surcharge the tunnel and force flow through generally in as described in Abbey Mills Transfer above. This would enable significant CSO flows from Abbey Mills to be transferred to Beckton for discharge direct to the River Thames.

As this potential option for early implementation terminates at Beckton it will be possible to drain the accumulated flow in the tunnel system to treatment. Assuming a draindown period of 48hours this would result in a maximum average draindown rate of 1.60m^3/s or 138Mld. For this duration the flow to the works will be increased above the average flow as follows:

Year	Average Flow (Mld)	Notional Maximum Full Treatment (Mld)
2006	1344	1482
2016	1467	1605
2021	1527	1665

These maximum flows are within the full treatment rates proposed for the AMP4/5 upgrade for Beckton.

2.14 OPTION 2A



2.14.1 Scope of East Tunnel

Abbey Mills to Beckton 5.7km @ 13.0m diameter tunnel
Approximate volume 769,000m^3
Construction shafts: 1nr
Pump-Out Shaft at Beckton STW
Overflow Shaft at Beckton STW
Bypass Tunnel: 1.3km @5m diameter with construction shaft and overflow structure

2.14.2 Scope of CSO interception works for East Tunnel

Abbey Mills only intercepted

2.14.3 Scope of Pumping and Power Plant for East Tunnel

The maximum average draindown rate of 385Mld is equivalent to 4.46m^3/s. In order to achieve this average rate the peak capacity required is 7.35m^3/s. The envisaged pumping plant consists of 4 units (3 duty, 1 standby) each capable of 2.45m^3/s, approximate head of 85m giving a nominal power rating of 2.8Mw. The maximum power requirement with all duty pumps running would be approximately 8.4Mw

2.14.4 Scope of West Tunnel

Homefield to Heathwall; 10.7km @ 7.6m; Volume 492,000m^3.
Construction shafts: 1nr ;
Pump-Out Shafts: 1nr ; return to system
Link tunnel to north of river

2.14.5 Scope of CSO interception works for East Tunnel

The seventeen Category 1 and 2 CSOs between Homefield and Heathwall will be intercepted.

The Category 1 CSOs include:
Acton, West Putney, Hammersmith PS, Putney Bridge, Frogmore, Jews Row, Falconbrook PS, Lots Road PS, Ranelagh, Western PS, South West Storm Relief and Heathwall PS.

The Category 2 CSOs include:
Stamford Brook, North West Storm Relief, Church Street, Queen Street and Smith Street.

2.14.6 Scope of Pumping and Power Plant for West Tunnel

The maximum average draindown rate of 246Mld is equivalent to 4.46m^3/s. Following the rainfall event and return to normal flows the maximum draindown rate that can be accommodated by the “spare” capacity afforded by LL1(S) and LL2(S) interceptor sewers is approximately 2.3m^3/s. Therefore additional capacity is required by transferring some of the draindown flow to the Beckton catchment. The LL1(N) can accommodate 1.0m^3/s.

The pump-out of the tunnel draindown flows will need careful control to ensure that the spare capacity of the interceptor sewers is not exceeded causing spill to the river or localised flooding.

Three sets of pumps would be required each dedicated to discharge to the LL1(S), LL2(S) via rising main in existing South West Storm Relief Sewer and LL1(N) via additional Cross Thames Link tunnel.

The maximum pump rating required is summarised in the following table

Pump Set	Nr of units Duty (standby)	Max Pump Output (m^3/s)	Duty Head (m)	Power (kW)
LL1(S)	2 (1)	2.36	75	1,200
LL2(S)	1 (1)	0.75	70	800
LL1(N)	1 (1)	1.50	70	1,600

The maximum power requirement with all duty pumps running would be approximately 4.8Mw

2.14.7 Treatment

For the draindown from the West tunnel, a reasonable estimate of the split between Crossness and Beckton treatment works would be approximately 80:20 for most events. However the potential maximum rates of draindown flow to Crossness and Beckton would be

Catchment	Maximum capacity of receiving interceptor sewers (m^3/s)	Additional treatment (Mld)
Crossness	2.3	199
Beckton	1.0	86

The maximum average draindown from the west tunnel to the Crossness catchment is within the improved flow to full treatment under the proposed AMP4/5 upgrades. Therefore it should be possible to accommodate this draindown flow without further upgrades.

The maximum average draindown rate for the east tunnel is 385Mld. However draindown from the west tunnel could add an additional 1m^3/s or 86Mld. Therefore the required notional Full Treatment rate is 1,998Mld.

2.14.8 Draindown and Flushing

As the east and west tunnels are separate systems they would be drained and flushed independently. They are also single lengths of tunnel and cannot benefit from sequential flushing as the full tunnel options.

The most upstream shaft at Homefield on the west tunnel would include a full height division wall and penstock to retain either storm flow or water abstracted from the river for subsequent release for flushing. The division wall would also incorporate a high level overflow weir to limit the depth of stored flow in the shaft. Similarly the Abbey Mills shaft on the east tunnel would incorporate a similar full height division wall, with high level overflow weir and penstock but would only retain storm flow for flushing.

The only flushing possible for these tunnel lengths is release of the stored storm water (or water abstracted from the river) from the upstream shafts after draindown. This stored volume is relatively small compared with the overall tunnel volumes, therefore re-suspension of deposited material will be less effective for these tunnel lengths.

2.14.9 Ventilation and Odour Control

The ventilation and odour control system for the east tunnel would consist of a ventilation intake at Abbey Mills and exhaust at Beckton with odour control plant if necessary. For the west tunnel the intake would be at Homefield with the exhaust, complete with odour control plant at Heathwall.

2.14.10 Abbey Mills Transfer

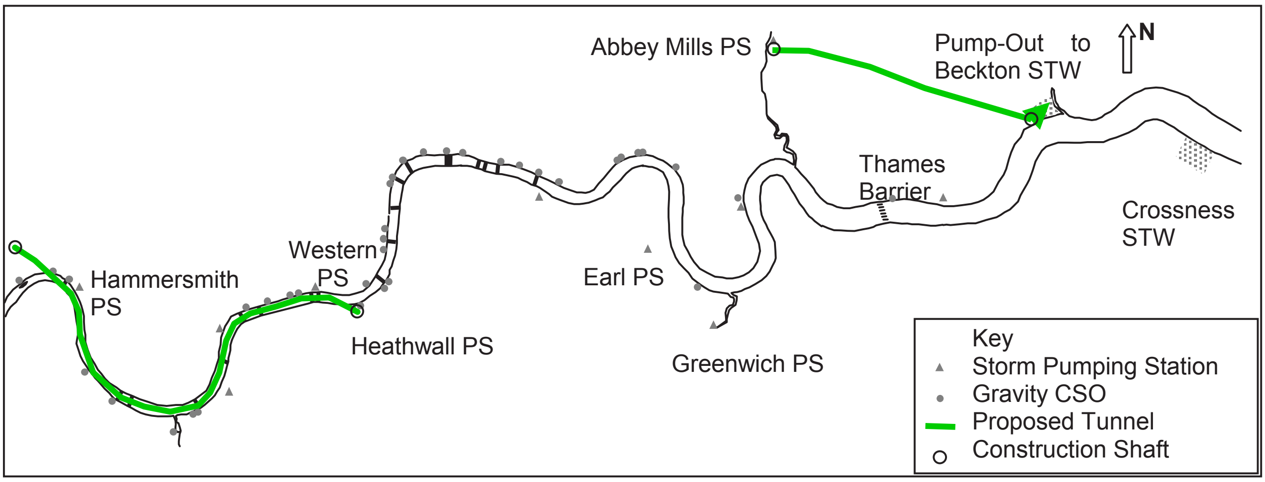
As the east tunnel is independent from the west tunnel and passes directly from Abbey Mills to Beckton, the operational intervention to effect this transfer, consists of switching from gravity interception at Abbey Mills from the Station F suction culvert to pumping interception. As the east tunnel nears completely full, the penstock between the suction culvert and main shaft would be closed and the penstock on the connection between the discharge culvert and main shaft opened.

The level would continue to rise automatically starting Station F pumps, which would then force flow into the tunnel, surcharging it sufficiently to push flow through the isolated tunnel kegs to Beckton and then via the overflow tunnel from the shaft upstream of the pumping station shaft to discharge to the main outfall culvert.

2.14.11 Potential Early Implementation

There is only one potential option for early implementation which is to construct the eastern tunnel first at its full diameter. Draindown of the tunnel would impose a maximum additional flow over average flow of 4.46m^3/s or 385Mld, requiring a notional maximum flow to full treatment of 1,729Mld at 2006 (based on current average flow), then 1,852Mld projected to 2016 or 1,912Mld for 2021. The current maximum flow to full treatment capacity would be exceeded, therefore the works would have to be extended to accommodate the draindown flows.

2.15 OPTION 2B



For this option the east tunnel is reduced to 10m in diameter. This reduction in storage volume is augmented by a significant increase in treatment capacity at Beckton to maintain a similar frequency of bypass as Option 2a. The west tunnel for this option is identical to Option 2a

2.15.1 Scope of East Tunnel

Abbey Mills to Beckton 5.7km @ 10.0m diameter tunnel ;
Approximate volume 455,000m^3
Construction shafts: 1nr
Overflow Shaft at Beckton STW
Pump-Out Shaft at Beckton STW
Bypass Tunnel: 1.3km @5m diameter with construction shaft and overflow structure

2.15.2 Scope of CSO interception works for East Tunnel

Abbey Mills only intercepted

2.15.3 Scope of Pumping and Power Plant for East Tunnel

The maximum average draindown rate of 228Mld is equivalent to 2.64m^3/s. In order to achieve this average rate the peak capacity required is 5.52m^3/s. The envisaged pumping plant consists of 2 units (1 duty, 1 standby) each capable of 2.76m^3/s, approximate head of 85m giving a nominal power rating of 3.5Mw. The maximum power requirement with all duty pumps running would be approximately 3.5Mw

2.15.4 Scope of West Tunnel

The scope of the west tunnel, CSO interception works, pumping and power plant are identical to Option 2a.

2.15.5 Treatment

The treatment requirements associated with the west tunnel are identical to that described for Option 2a. However in order to augment the reduced storage capacity of the east tunnel at 10m in diameter the treatment capacity at Beckton needs to be increased to 2700Mld. This maximum treatment capacity is equivalent to the nominal maximum capacity of the existing inlet works and primary treatment plant and therefore can be achieved by upgrading the secondary and final treatment streams together with supporting processes. The cost of any potential further increase in capacity would be significantly higher as all treatment processes would be subject to increase.

It is also assumed that this additional flow can be transferred to Beckton via the NOS (max flow rate approximately 31m^3/s) by controlled diversion of flows at Abbey Mills. This avoids the requirement of high capacity pumping plant for the East tunnel

2.15.6 Operation, Draindown and Flushing

For both the east and west tunnels operation, draindown and the limitations of the flushing cycle would be as described for Option 2a.

2.15.7 Ventilation and Odour Control

The ventilation and odour control system for the east tunnel would consist of a ventilation intake at Abbey Mills and exhaust at Beckton with odour control plant if necessary. For the west tunnel the intake would be at Homefield with the exhaust, complete with odour control plant at Heathwall.

2.15.8 Abbey Mills Transfer

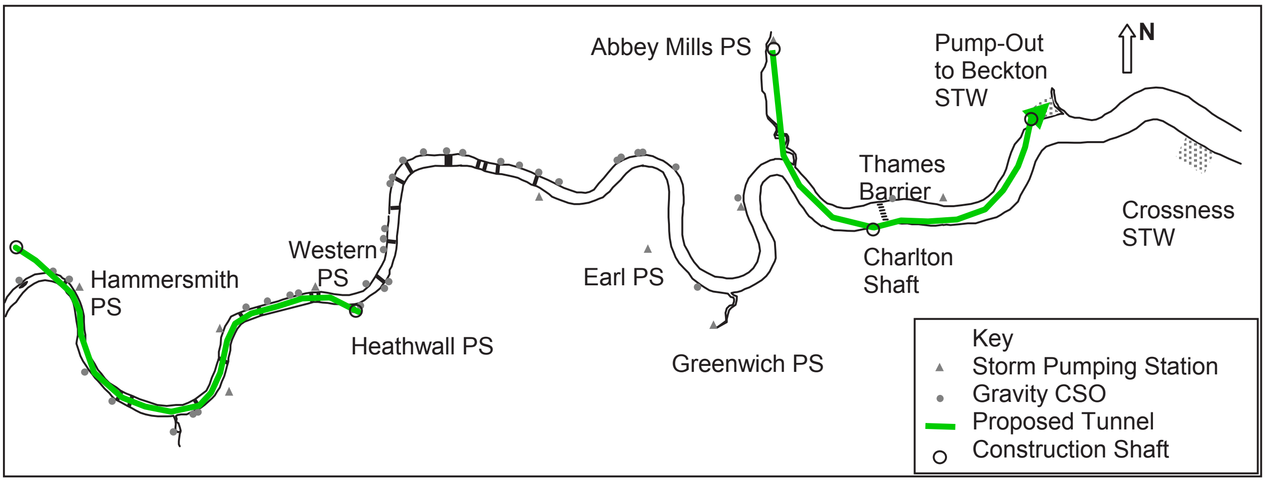
As the east tunnel is independent from the west tunnel and passes directly from Abbey Mills to Beckton, the operational intervention to effect this transfer, consists of switching from gravity interception at Abbey Mills from the Station F suction culvert to pumping interception. As the east tunnel nears completely full, the penstock between the suction culvert and main shaft would be closed and the penstock on the connection between the discharge culvert and main shaft opened.

The level would continue to rise automatically starting Station F pumps, which would then force flow into the tunnel, surcharging it sufficiently to push flow through the isolated tunnel kegs to Beckton and then via the overflow tunnel from the shaft upstream of the pumping station shaft to discharge to the main outfall culvert.

2.15.9 Potential Early Implementation

There is only one potential option for early implementation which is to construct the eastern tunnel first at its full diameter. Draindown of the tunnel would impose a maximum additional flow over average flow of 2.64m^3/s or 228Mld, requiring a notional maximum flow to full treatment of 1,572Mld at 2006 (based on current average flow), then 1,695Mld projected to 2016 or 1,755Mld for 2021. These maximum flows are within the full treatment rates proposed for the AMP4/5 upgrade for Beckton.

2.16 Option 2c



For this option the east tunnel is reduced to 10m in diameter, however the route between Abbey Mills and Beckton is taken via Charlton. The overall storage volume is therefore similar to that of the east tunnel for Option 2a. The west tunnel for this option is identical to Option 2a

2.16.1 Scope of East Tunnel

Abbey Mills to Charlton 5.0km @ 10.0m diameter
Charlton to Beckton 4.0km @ 10.0m diameter
Approximate volume 769,000m^3
Construction shafts: 2nr
Pump-Out Shaft at Beckton STW
Overflow Shaft at Beckton STW
Bypass Tunnel: 1.3km @5m diameter with construction shaft and overflow structure

2.16.2 Scope of CSO interception works for East Tunnel

Abbey Mills and Charlton only intercepted

2.16.3 Scope of Pumping and Power Plant for East Tunnel

The maximum average draindown rate of 446Mld is equivalent to 4.46m^3/s. The required pumping plant is therefore identical to Option 2a. In order to achieve this average rate the peak capacity required is 7.35m^3/s. The envisaged pumping plant consists of 4 units (3 duty, 1 standby) each capable of 2.45m^3/s, approximate head of 85m giving a nominal power rating of 2.8Mw. The maximum power requirement with all duty pumps running would be approximately 11.2Mw

2.16.4 Scope of West Tunnel

The scope of the west tunnel, CSO interception works, pumping and power plant are identical to Option 2a.

2.16.5 Treatment

The treatment requirements associated with both the east and west tunnels are identical to that described for Option 2a.

2.16.6 Operation, Draindown and Flushing

For the west tunnel the operation, draindown and the limitations of the flushing cycle would be as described for Option 2a.

For the east tunnel sequential draindown of the two tunnel legs can be incorporated into the operation to facilitate better flushing and removal of deposition. The envisaged operation would be as described below:

The upstream shaft at Abbey Mills would include a full height division wall and penstock to retain either storm flow for subsequent release for flushing. The division wall would also incorporate a high-level overflow weir to limit the depth of stored flow in the shaft and allow Abbey Mills CSO flows to pass to storage in the tunnel. The shaft at Charlton would incorporate an in-line penstock.

During filling the penstock in the main shaft at Abbey Mills would be closed to retain storm water for flushing at the end of the cycle and the penstock in the Charlton shaft would be open to allow distribution of intercepted flow to storage.

At the start of the draindown and flushing cycle the penstock at Charlton would be closed and the following sequence followed:

1. Start pump-out and draindown the Charlton to Beckton tunnel leg
2. Open the penstock at Charlton for the tunnel leg to Abbey Mills. This leg will empty quite rapidly into the empty Charlton to Beckton leg, generating flow velocities to re-suspend deposition in both legs. Continue pump-out to draindown.
3. Open the penstock at the Abbey Mills shaft to release the stored storm water as a final flush for this tunnel leg. Continue pump-out to draindown.

2.16.7 Ventilation and Odour Control

The ventilation and odour control system for the east tunnel would consist of a ventilation intake at Abbey Mills and Charlton with exhaust at Beckton with odour control plant if necessary. For the west tunnel the intake would be at Homefield with the exhaust, complete with odour control plant at Heathwall.

2.16.8 Abbey Mills Transfer

As the east tunnel is independent from the west tunnel the operational intervention to effect transfer is similar to Options 2a and 2b and therefore consists of switching from gravity interception at Abbey Mills from the Station F suction culvert to pumping interception. As the east tunnel nears completely full, the penstock between the suction culvert and main shaft would be closed and the penstock on the connection between the discharge culvert and main shaft opened. At this point the Charlton CSO connection would have to be isolated to prevent backflow from the tunnel through this outlet. Therefore an additional high-level isolation penstock would be required in the Charlton Shaft.

The level would continue to rise automatically starting Station F pumps, which would then force flow into the tunnel, surcharging it sufficiently to push flow through the isolated tunnel kegs to Beckton and then via the overflow tunnel from the shaft upstream of the pumping station shaft to discharge to the main outfall culvert.

2.16.9 Potential Early Implementation

There are two potential options for early implementation of the eastern section of tunnel, which are similar in concept to that described for Option 1a, however the tunnel diameters differ:

1. Abbey Mills to Charlton at 10m diameter
2. The full eastern tunnel at 10m diameter

There are no treatment implications associated with the first option as accumulated flows would be pumped out to the river and there would be no additional flow passed to the treatment works.

The second option terminates at Beckton, therefore the accumulated flow could be pumped out to treatment. Assuming a draindown period of 48hours this would result in a maximum average draindown rate of 4.46m^3/s or 385Mld. This requires a notional maximum flow to full treatment of 1,729Mld at 2006 (based on current average flow), then 1,852Mld projected to 2016 or 1,912Mld for 2021. The current maximum flow to full treatment capacity would be exceeded, therefore the works would have to be extended to accommodate the draindown flows.

3 DETAILED OPTIONS ASSESSMENT

3.1 INTRODUCTION

This section includes an assessment of each option and its variants, including potential early phases, with regard to cost, programme of implementation, construction and constructability, key issues and risks and interception performance.

The specific aspects of each option are discussed below under separate assessments for each. The outline scope of each option is described in Options Review and further recorded in more detail in the Tunnel Development Report (Ref 1).

To a large extent the construction methods are generic, varying only by size or extent for each option, and are therefore described below. As all options are based on similar construction methods many of the risks and issues are also generic. Specific exceptions where appropriate are discussed in the separate assessments.

3.2 CAPITAL COSTS ESTIMATES

3.2.1 Introduction

The capital costs for each option have been estimated on a common methodology, and include:

1. Tunnel, main shaft and CSO interception works
2. Pumping and power plant
3. Treatment plant work
4. Risk & Contingency for Tunnel & Shaft works)
5. Risk & Contingency for Treatment works
6. Resource costs (detailed design, P&E, specialist consultancy etc)
7. Land and compensation costs

3.2.2 Tunnel, main shaft and CSO interception works

The detailed budget estimates for the tunnel, main shaft and CSO interception works are based on the concept designs, methodologies and construction programmes prepared under the Tunnel Development Study. It is assumed that the works would be undertaken as single joint venture contracts at 2006 prices.

Exclusions from these budget estimates are: Design; Strengthening Third Party Services; Mechanical and Electrical Fit-out; Land Acquisition and Planning Fees; Environmental Requirements; Thames Water, Environment Agency and Consultants Costs or Fee; Inflation from 2006.

The estimates are prepared on a resource and time basis with the exception of specialist sub-contract works. The advantage of detailing the pricing down to the individual elements of each structure is threefold:

- It provides a more accurate estimate
- It allows cost optioneering exercises to be undertaken quickly and accurately
- The project costs can be easily sub-divided into multiple contracts if required

A management fee allowance of 8% for Head Office overheads and profit has been included.

Insurances have been assessed at 7% of the overall contract value. This is a mean ascertained figure without commitment. Insurance companies may not be keen to take on the risks and if one were to provide insurance it would be heavily caveated and contain abnormal excesses. Self insurance of the project works may be most economic.

Each structure in the proposed designs was broken down into its constituent elements and each element was priced on the basis of labour, plant and material etc. Using the Charlton Drive Shaft as an example, it was broken down into the following elements:

- Diversion of existing services
- Mobilisation
- Provision of hard standings
- Depressurisation wells
- Horizontal conveyor system
- Development of hydro-fraise for depth
- Mobilisation of diaphragm walls
- Setting our for diaphragm walls
- Concrete guide walls
- Diaphragm wall construction
- Provision of lagoons
- Disposal of Bentonite
- Demobilisation of diaphragm wall resources
- Base slab
- Shaft excavation
- Muck away
- Grout block for drives
- Machine break outs
- Tunnel eye head-wall
- Benching
- Internal lining
- Shaft finishes (excluding mechanical and electrical)
- Cover slab
- Demobilisation

The other main structures were similarly broken down into their constituent elements. Generally the works will be undertaken in double 12-hour shifts, which means, particularly for tunnelling, a three-gang regime allowing for days off. The level of labour and plant resources required for each activity has been agreed with Amec, as part of their input to the Tunnel Development study. The resource allocation was verified by examination of other contractors' build-ups. Material quantities were measured from the concept design drawings.

Specialist sub-contractors have been consulted in depth on their areas of expertise e.g. the costs of diaphragm wall construction has been discussed with both Bachy Soletanche and Spie Foundations

3.2.3 Pumping and power plant

The budget cost for supply and installation of the pumping plant, together with the switchgear and power generation plant were estimated in collaboration with the pump manufacturers KSB, power generator manufacturers and supplemented by costs extrapolated from other projects

3.2.4 Treatment plant work

The budget estimates for the additional treatment plant were prepared by the treatment team as part of the study work reported in Solutions Working Group Report Volume 2.

3.2.5 Risk & Contingency for Tunnel & Shaft works

As part of the Risk Identification Process each risk register was priced using Base Estimates and three point assessments of minimum, maximum and most likely costs and percentage probability within the Thames Risk Model. The model works using @Risk statistical modelling to derive an overall value for both Contingency Estimating Contribution and Project Contingency Risk Contribution in order to derive a Risk Allowance/Contingency.

The Risk Models were run using 5000 simulations and P50 assessment on the Predictability Curve. The overall percentage addition for Risk ranges between 12% and 16.5% of the base tunnel costs.

3.2.6 Risk & Contingency for Treatment works

A separate Risk Identification Process was followed for the treatment works. This is reported in Solutions Working Group Report Volume 2.

3.2.7 Resource costs (detailed design, P&E, specialist consultancy etc)

These resource costs cover detailed design, planning and environmental work, specialist consultancy, project management. Significant teams will be required to progress the project through the next stages of design development, planning and construction. It is likely that the specialist consultancy work will include extensive computer and physical modelling.

There will also be significant investment in topographical surveys, site investigation, flow and sample monitoring as well as baseline monitoring of third party structures.

3.2.8 Land and compensation costs

Each option requires land acquisition for some of the main shaft sites. It is likely to require purchase by compulsory purchase order and hence there will also be compensation costs associated with relocation of businesses and amenity.

Whilst the main tunnel route follows the course of the river, section unavoidably pass under properties. Pre-construction and post-construction surveys will therefore be required and it is likely that some compensation may be inevitable.

The CSO Interception works are mainly in the highway, but may also impact on some local businesses, therefore some compensation costs need are allowed for this eventuality.

3.3 Operational Costs

Using the outline designs prepared for each option, Operational Cost estimates have been prepared by consideration of the following components for each option:

- Standing inspection and maintenance costs for tunnel operation,
- Energy consumed by pumping to lift flows from the tunnel to the inlet to the treatment works,
- Maintenance of the mechanical and electrical equipment within pumping stations,
- Energy consumed by ventilation fans,
- Consumables for odour control equipment,
- Maintenance of ventilation and odour control equipment
- Annual internal inspection of the tunnel
- Annual cleaning of the tunnel,
- Disposal costs for material collected during tunnel cleaning,
- Additional costs for disposal of screenings and grit discharged to Beckton STW by the tunnel.

These vary according to the overall extent of each scheme and the total volume of flow intercepted by each option.

Standing costs for inspection and maintenance of the tunnels, shafts and CSOs has been based on an allowance of 2 days input by the maintenance team for each of an assumed 60 rainfall events per annum.

Energy consumption to operate pumps required for each option has been estimated by calculation of the energy required to operate the main pumps to lift the average annual volume of intercepted flow to treatment. This equates to approximately 66 days per annum of pumping at the maximum capacity. Provision has then been added for the power required by the flushing pumps, the infiltration pumps and the dry well sump drainage pumps. A further allowance has then been made for power requirements for plant that operates intermittently, such as the gantry cranes, personnel access lifts, pumping station lighting, etc. The cost of energy is based on £0.08/kWhr

Costs for annual maintenance of mechanical and electrical equipment have been assessed at 1% of the capital value of the installed plant.

Power costs for operation of inlet and exhaust ventilation fans at shafts have been calculated based on estimated loads of 10kW per shaft operating continuously.

Odour control equipment is assumed to be activated carbon filters. An allowance has been made for replacement of the media annually and for safe disposal of the exhausted media.

Provision has been made for routine maintenance of ventilation shafts, fans, ventilation kiosks and odour control equipment by allowance of inputs for one day per week each for a Roundsman, Ventilation technician and Odour technician.

It is anticipated that each tunnel length would be subject to a full inspection on a five-year cycle. Using Option 1c, which includes 5 individual tunnel lengths, one length per year would be fully inspected. Further tunnel entries to check for and remove any sewage debris not removed by the flushing regime, particularly just upstream of the pumping station shaft(s). The estimates assume that the latter activity takes place at a frequency of one length of tunnel between shafts being cleaned annually.

While procedures will be developed to allow efficient and safe access to the tunnel on each of these inspections, it is anticipated that considerable time will be expended in arranging, managing and clearing up after each entry inspection. Budgets have been prepared on the basis that the each inspection may require the team to spend an average of 10 days in planning, preparation, entry/inspection, close down and site rehabilitation. Health and safety requirements will dominate arrangements for each entry, which will require temporary ventilation plant powered by mobile generators to be installed at each shaft site and mobile cranes to be available at shafts either side of the tunnel length to be entered. For health and safety reasons it is assumed that each item of plant will need to be duplicated on site to ensure standby facilities are always available.

An allowance has been made in the estimate for the volume of material that may need to be removed from the tunnel during each cleaning visit and for its disposal. Allowance for additional screenings and grit that will be transferred by the tunnel from the CSOs to the treatment works has been included in additional operating costs for Beckton treatment work.

3.4 IMPLEMENTATION PROGRAMME

The implementation programmes for each option are based on the indicative construction programme extended to include the required pre-construction activities. The detailed elements of the construction programmes were built up on the basis of reasonable duration of construction activities. The overall implication of such a programme is a reasonable but slightly optimistic indication of completion as there is no allowance for delay. These detailed programmes were used as the basis of producing the cost estimates before the application of the risk and contingency sums. In recognition that there may be delays a time contingency of 15% was applied to the pre-construction activities and a 10% time contingency applied to the construction activities.

The pre-construction activities include planning, design procurement and tender. Early contractor involvement is considered vital to in order refine the design and assist development of the detailed planning submissions. Two formats of the pre-construction activities were developed.

The first is for implementation of options that include land acquisition, which is likely to require compulsory purchase and fairly extensive periods for the planning process, as several London Boroughs and other stakeholders will be involved. Activity durations for development of the design, tender process and appointment of the contractor are also included. Overall 52 months, or 60 months including time contingency, has this allowed for this “front-end” of the programme.

The second format is for early implementation of a first phase of an option, such as the Abbey Mills to Beckton tunnel for Option 1c. A more condensed period for the pre-construction activities is considered appropriate as a reflection that the works are confined to one London Borough, the fast track appointment of the contractor and that there is no requirement for site acquisition. In this manner the duration of pre-construction activities can be condensed to 18 months. An earlier start date of January 2007 has been taken because of the perceived potential urgency to complete these works before the Olympic period.

Achievement of this accelerated programme requires a prompt ministerial decision to proceed in January 2007. It also requires remediation works at Beckton STW to be carried out in advance of planning permission.

If this accelerated programme for the pre-construction activities is not invoked and the more extensive processes followed, construction start would be delayed at least to July 2011 and completion would not be at least until March 2015.

As the compulsory purchase process is normally fairly extensive and interlinked with the planning process, acquisition of the sites for the main shafts is programme critical, therefore early implementation options that require land acquisition cannot follow the condensed “front-end” programme.

3.5 Construction Methodology

This section summarises the very detailed work undertaken by Faber Maunsell and Amec, which can be found in the Tideway Tunnel Development report

3.5.1 Main Tunnel Construction

There are three basic technical choices for driving the main tunnel:

1. Earth Pressure Balance Tunnel Boring Machine (EPB TBM)
2. Slurry TBM
3. Open face TBM

The TBM choice will be governed by a number of key criteria, as follows:

- External.
- The geology of London Clay, Lambeth Group Beds, Thanet Sand and Chalk.
- Water pressures on the TBM and lining will range from 30m head (3 bar) at Homefield up to 80m head (8bar) at Beckton
- There will be considerable amount of wear to the cutting tools on the head of the TBMs. These will need changing at intervals.

Within this study these methods have been considered in great detail with experienced TBM manufacturers and are other experienced tunnelling contractors, leading to the following conclusions:

- Open Face TBM could be appropriate for drives in London Clay, however the drive between Heathwall and Homefield will not be entirely within this strata and may be subject to high groundwater pressures in sand layers near to Heathwall. Therefore an EPB TBM is recommended

- The drive between Heathwall and NESR would be in mixed ground of the Lambeth, Harwich and Upnor beds with high groundwater pressures, therefore EPB TBM would be more appropriated despite encountering a short section in Chalk.
- A Slurry TBM is considered more appropriate for drives in chalk as the transportation of excavated material in a slurry medium significantly reduces wear at the cutting face
- Consideration should also be given to a TBM that can be operated in both EPB and Slurry modes, such as the hydroshield type TBM that was used on the Socatop project in France.

3.5.2 Main Shaft Construction

All the main shafts and wet well shafts are proposed to be 25m I.D. with the exception of Beckton and Heathwall pumping station shafts which will be 38m I.D. to provide sufficient footprint for the pumping plant. A minimum 25m I.D. diameter shaft is considered to be the most practicable size for either launching or receiving the tunnel boring machines (TBMs) conducive with the required depth of the shafts. The 6m and 7.2m TBMS could be launched with a nominal provision for portal works, whereas the 10m and 13m TBMs may require the construction of significant underground launch chambers to facilitate assembly of the TBMs.

The main shaft at Homefield would be entirely in London Clay and therefore segmental construction by underpinning would be appropriate. For all other main shafts the ground conditions are mixed and water bearing, therefore the diaphragm wall method is proposed. Where shafts are excavated to a significant depth in chalk and the groundwater can be controlled the alternative sprayed concrete, or a hybrid approach of sprayed concrete in conjunction with diaphragm wall technique could be considered.

The main shafts would be used as either drive shafts or reception shafts for tunnel construction. At the drive shaft sites temporary jetties or extensions to existing jetties would be provided to facilitate transportation of the excavated material and tunnel segments by barge.

It is proposed to locate the main shafts at Beckton in the Beckton Rectangle. This site will require extensive remediation prior to any site establishment. This will involve the removal, treatment and disposal of highly contaminated soil. It is essential that this activity does not restrict access for shaft construction. On the programmes the remediation has been shown to occur in advance of site possession for the Tideway works.

The preferred location of the most westerly shaft is at Homefield. However it is realised that environmental constraints and public objections may increase the uncertainty of achieving access to this site. The feasibility of an alternative location at Hammersmith located in the tidal margins of the river close to the river wall at the end of Chancellor’s Road has been investigated. A temporary piled area in the river would be constructed to facilitate shaft sinking and shield recovery. The construction of the shaft on the river foreshore will be more complex involving rider tunnels for the transfer of intercepted flow to the shaft as well as side entry tunnels for operational access and ventilation. Access to the shaft for inspection and maintenance will be more problematic. As this shaft would be less satisfactory for health and safety reasons it cannot be promoted as a reasonable alternative.

3.5.3 CSO Interception Shafts

It is proposed that as far as is practicably possible the shafts will be constructed using dry caisson techniques. This is considered to provide greater control of the shaft verticality during construction compared with wet caisson techniques. This is particularly critical given the required construction depths exceeding 50m. Recent reviews of the construction risks have indicated that dry/wet caissons can provide a safer method of construction than underpinning techniques. In chalk the option exists for changing to a sprayed concrete support structure.

Dry caisson methods also enable the construction of under-reamed base slabs to provide anti-floatation reaction. The potential hydrostatic uplift on the deep shafts would require a substantial quantity of tension anchors or an extremely large concrete base. It is considered that under-reaming provides a more economical and reliable solution.

To enable a dry caisson to be achieved dewatering, depressurisation, fissure grouting or ground freezing will be required as appropriate.

3.5.4 CSO Connection Tunnels

The previous studies proposed adopting three CSO connection tunnel and shaft sizes as follows:

Connection Tunnel Diameter	Shaft diameter
1.5m I.D. pipejack	6.0m I.D.
2.0m I.D. pipejack	7.5m I.D.
3.0m I.D. tunnel	9.0m I.D.

Although from strictly hydraulic considerations smaller sized tunnels can be justified, the 1.5m I.D tunnel was adopted for Health and Safety considerations. The gradient of the connection tunnel has been set at 1 in 200 and the connection made to the main tunnel on its centreline.

The choice of TBM method is dependent on the ground type, size and depth. In most cases Earth Pressure Balance (EPB) technology has been proposed primarily to control water ingress. This method would also minimise the amount of surface backup equipment required. The option still exists for the use of slurry type TBMs and separation plant can be placed in moderately compact containers. The exception to EPB or slurry would be in London Clay, where open face machines may be practicable. In reality however the same TBMs would be utilised meaning that the number of machines required for the CSO connection tunnels could be rationalised to the key sizes.

The shaft break-out and connection methods for each strata type would be similar, irrespective of the drive direction. Groundwater control by means of grouting, dewatering, fissure grouting or ground freezing would be implemented where required to allow for the initial break out with the TBM through a pre-constructed portal consisting of a headwall and seal can. The groundwater controls would only be discontinued when the connection tunnel was fully established.

TBM reception into the main tunnel would utilise special opening segments installed in the main tunnel at the connection points. Where required groundwater control using ground freezing installed from within the main tunnel would be instigated prior to the connection being made.

Consideration has been given to the disposal of waste materials, excavated spoil, water etc. and the delivery of materials, in particular segments and jacking pipes. Due to the restriction on the compound sizes at many of the shafts muck storage will difficult and therefore co-ordination of muck away wagons will be critical.

Allowance will also be made for water treatment at each compound to deal with both tunnel and surface generated water. The philosophy for the works as a whole is to maximise use of the river to transport both spoil and incoming materials, in particular pipes and segments from the designated project pre-casting facility. Where the CSO shafts are adjacent to the riverside, spoil will be conveyed directly to flat bottom barges with segments and pipes unloaded from barges. Other sites would be serviced by road transport to and from centralised locations for disposal and materials delivery.

3.6 PUMPING REQUIREMENTS

The terminal pumping stations are required at the eastern ends of all tunnels to lift flows either into the treatment works at Beckton (All Options) or into the existing trunk sewers serving Beckton and Crossness (Options 2a, 2b and 2c only). These pumping stations will be constructed within the tunnel shafts, arranged so that their base is below the invert level of the incoming tunnels, but with access for maintenance being provided from a pumping station superstructure constructed at ground level.

The proposed designs for the pumping stations include separate shafts to act as wet and dry wells. The wet wells are shafts of diameter approximately 25m, which also form the terminations of the storage tunnels. Adits will connect between the wet and dry well shafts and contain two pump suction bus mains.

The proposed pumps have horizontal shafts, directly coupled to their drive motors. The recommended arrangement for the pumping equipment is for this to be arranged either side of bus suction pipes on the centreline of the shaft.

It is proposed that as a minimum one standby pump is installed for each design duty to ensure that the station remains operational should a duty pump fail. Water-cooled motors are preferred to simplify problems of heat removal from the dry well shaft, but introduce requirements for space to be available at ground level for individual circulation pumps for each motor and associated air blast coolers.

To be able to match pump output to the available spare treatment capacity at Beckton STW or the spare sewer capacity downstream of Heathwall Pumping Station, the pump outputs need to be variable. The pumps also need to be able to cater for a range of delivery heads from that which will occur when the tunnel has filled and overflowed, to that which will occur when the tunnel is almost empty. To achieve these requirements all tunnel drain-down pumps will be fitted with variable speed drives.

It is anticipated that the tunnel will receive a significant volume of grit and screenings from the CSO discharges. In selection of the pumps to be installed, special attention will be paid to their ability to handle screenings and grit. Current proposals are designed around pumps specifically designed to handle mineral slurries, but further testing will be required to demonstrate that such pumps are able to cope with sewage screening.

It is to be expected that the peak screenings and grit concentrations will be pumped from the tunnel as the level of the tunnel contents is drawn down close to the tunnel invert. To avoid placing excessive loadings on screenings removal and grit separation facilities in Beckton STW, smaller capacity pumps to be used at this stage in the drain-down cycle. These are referred to as flushing pumps and will be used during the flushing cycles, as penstocks are opened to discharge the flows from the next volume of tunnel to be emptied, sweeping accumulated debris to the pumping shaft.

To avoid the need to install non-return valves and isolating valves on each pump delivery pipeline from pumps at Beckton, it is proposed that all pumps will discharge through an individual delivery pipeline which will discharge at ground level. Each pump will be fitted with a suction gate valve and a suction knife valve. The latter valve will be operated to allow maintenance of the gate valve. Both valves will provide the necessary double isolation whenever a pump is removed for maintenance.

A similar arrangement will be adopted for the majority of the pump sets at Heathwall. The exception will be on the pumps which discharge into the Lower Level Southern Outfall Sewer, which require a 4 km rising main. These pumps will need to be fitted with non-return valves and delivery valves.

Once a preferred option is identified, it will be necessary to undertake some CFD and physical modelling of the proposed pumping station arrangement to ensure that the proposed pumps have stable duty points and adequately sweep debris from the wet sump to prevent any long term accumulations which could lead to either odour problems or pump blockage.

3.7 Issues and Risks

The risk identification process included:

- Risk Identification Workshop
- Generation of a Risk Register
- Sensitivity and sensibility review
- Derivation of Risk Allowance and Contingency

The process focused on three generic elements of the options, variants and phasing:

- Full Tunnel Options (Options 1a – 1c)
- East/West Tunnel Options (Options 2a – 2c)
- Early Implementation of a tunnel between Abbey Mills and Beckton

Many of the main risks identified were common to the Full Tunnel and East/West Tunnel Options and are listed below:

- Eastern Drive shaft sites become unavailable if delay in Ministerial approval
- Extended Phased delivery beyond option considered
- Ground conditions worse than expected
- Development during Olympic period in sensitive areas
- Planning requirements on Main Construction Working Areas (5nr)
- Unexpected complexity of utility diversions in CSO connections
- Limit to number of CSOs that can be worked on at any one time
- Certainty in achieving renewable energy requirements as part of Planning requirements
- Archaeology investigations greater than allowed
- Implications of any special planning conditions not envisaged at this stage

The following main risks, specific to the East/West Tunnel Options were also identified:

- EC find option not compliant with UWWTD
- Method of operation leads to over sophisticated control system, which is undeliverable (tunnel pump-out to interceptor sewers)

Finally the following main risks, specific to early implementation of a tunnel between Abbey Mills and Beckton were identified:

- Delay to Ministerial approval beyond Jan 07 - Failure to meet Olympics
- Price escalation within supply chain delivery over programme - not reflected in Inflation indexes
- Requirements of 106 agreements
- Effectiveness of planning strategy
- Lack of resource availability due to competing projects
- Impact of large diameter tunnel construction

The risk identification process clearly identifies the critical requirement for early Ministerial approval to ensure implementation of the Abbey Mills to Beckton tunnel as a first phase of Option 1c in before the Olympics. Early Ministerial approval is also critical in order to secure the eastern main drive shaft site. Ground conditions also feature highly in all options due which is only to be expected due to the nature of the works.

Specific issues and risk are further discussed in the assessment for each option

3.8 INTERCEPTION PERFORMANCE

3.8.1 Frequency of Bypass

Two catchment model approaches have been used to assess the interception performance of each option. The first utilised simplified models for a dataset of 34 years and the second used full model runs for a typical year. The first method is a crude simplification but gives a good estimation of the average frequency of bypass in terms of total volumes of flow. The model runs for the typical year, however, gives a better estimation of the relative volumes of interception for each option. The bypass frequency for the typical year is lower than average as there are fewer large rainfall events in this dataset.

The bypass frequency for Options 2a – 2c is quoted for the CSOs connected to the tunnel lengths. However these options do not intercept 16 category 1 and 2 CSOs in the central area, therefore these CSOs would continue to discharge unimpeded with the same frequency and volume of discharge as the existing situation. **Therefore in overall terms there is no reduction in spill day events.**

3.8.2 Dissolved Oxygen Compliance

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. This process is described in greater detail in the Water Quality Modelling Technical Report.

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 standard than Option 1b. Options 2a, 2b and 2c all fail the DO objective and hence are less likely to achieve sustainable fish populations.

3.9 ASSESSMENT OF OPTION 1A

3.9.1 Capital Cost

The overall capital costs for this option are summarised below:

Item	Cost (£M)
Tunnels, Shafts and CSO Interception works	1,208
Pumping, Electrical and Power Plant	130
Treatment Works for Tunnel Draindown	145
Risk & Contingency	309
Land and Compensation Costs	50
Resource costs for management and design, specialist consultancy	254
Total Cost for option	**2,096**

3.9.2 Operational Costs

The overall operational costs for this option are summarised below:

Item	Cost (£M)
Routine inspection and maintenance	1.52
Energy (pumping and ventilation)	3.67
Treatment of Tunnel Pump-out	2.19
Total Cost for option	**7.38**

3.9.3 Programme

Implementation of the complete option would require the full planning process and land acquisition, therefore the duration of pre-construction activities are judged to be approximately 52 months, or 60months with time contingency. There are two options for implementation of early phases, however both rely on acquisition of the Charlton site for this main shaft, therefore a similar duration for pre-construction activities is considered appropriate

The Abbey Mills to Beckton, via Charlton early phase does not take longer to construct as the two tunnel legs are carried out simultaneously. Therefore there is no difference in the overall duration of the implementation programme.

Option 1a	Start Date	Pre-construction Phase	Construction Start Date	Construction	Completion Date
Complete Option	March 2007	60 months (52 months)	Feb 2012 (Jul 2011)	92 months (84 months)	Oct 2019 (Jul 2018)
Either Early Phase	January 2007	60 months 52 months	Nov 2011 (May 2011)	58 months (53 months)	Oct 2016 (Nov 2015)

The main dates and durations quoted include a 15% time contingency for the pre-construction activities and a 10% contingency for construction. The figures in brackets exclude this contingency and represent the earliest dates and shortest durations

For the early implementation options an earlier start date of January 2007 has been assumed because of the perceived potential urgency to attempt completion before the Olympic period. The duration of construction is estimated from the full programme. The likely duration of the compulsory purchase process determines that the early phases cannot be implemented in time for the Olympics even without invoking the time contingency durations

3.9.4 Construction and Constructability

The construction methods are generally as described before.

For Option 1a the drive shafts would be located at Heathwall and Charlton. Temporary jetties will be required to effect transportation of bulk material by barge.

For either of the two early phases, Charlton would again be a drive shaft. However for the second option the shaft at Beckton would also be used as a drive shaft for the tunnel leg between Charlton and Beckton. Improvements and extension to the existing jetty at Beckton would therefore also be required.

3.9.5 Key Issues and risk

The particular risk relates to the surcharge of Charlton main shaft to invoke transfer of CSO flows from Abbey Mills. Should the isolating penstocks fail open then the main tunnel would also be surcharged resulting in backflow through upstream CSOs which would cause localised flooding. Backflow through the Charlton CSO connection would create localised flooding and restrict the capacity of Charlton storm relief, which may result in flooding further upstream. The main shaft at Charlton would also have to be extended above ground to prevent release of flow from the roof covers.

Due to this risk of potential flooding the transfer of Abbey Mills flows to discharge at Beckton for either the early phases or the complete option is not recommended.

3.9.6 Interception Performance

3.9.6.1 Complete Solution

The complete solution has a storage volume of approximately 1,618,000m^3 which acts in combination with the increased flow to full treatment at Beckton STW of 2,336Mld. Modelling results show that the interception performance in terms of average flows is as follows:

Bypass Frequency (Spill Day Events)		Typical Annual Volumes (m^3)		
Average	Typical Year	Bypass	Interception to tunnel	Interception Direct to Treatment
3 - 4	1	1,018,582	35,840,388	11,278,619

This system would be able to completely intercept all events except approximately 3 per year on average. For these events that exceed the system capacity, a volume equivalent to the tunnel storage volume will at least be intercepted thus significantly reducing the volume of discharge. Furthermore the first flush of the discharge will be intercepted, which would significantly reduce the polluting load.

In order to maintain the ability to transfer all Abbey Mills, that is to eliminate discharge to the River Lee, the tunnel legs from Abbey Mills to Charlton to Beckton would have to be surcharged by the Station F pumps as described for Abbey Mills Transfer.

In order to maintain the surcharge on this tunnel section it would have to be isolated from the remainder of the main tunnel and the Charlton CSO connection by penstocks in the main shaft at Charlton. Therefore if the isolation penstock failed open then the transfer of flow from Abbey Mills could not be invoked and discharge would revert to the River Lee. For the complete option this is only possible when the capacity of the system is exceeded, potentially three times per year.

3.9.6.2 Early Phases

3.9.6.2.1 Abbey Mills to Charlton (at 7.2m diameter)

The potential application of the first option would be to transfer a significant proportion of Abbey Mills CSO discharge away from the River Lee direct to the River Thames at Charlton. The existing pumping plant at Abbey Mills could be utilised to surcharge this leg of the tunnel and force flow into the River Thames against high tide.

The storage volume afforded by this leg of the tunnel is approximately 256,000m^3. During 2004 over 35 events exceeded this volume of discharge, therefore it is relatively insignificant compared with the volumes discharged from Abbey Mills and only provides nominal attenuation. The hydraulic capacity is therefore the critical factor for reducing discharge from Abbey Mills to the River Lee. If transfer capacity is insufficient discharge to the River Lee will be necessary to prevent upstream flooding.

Transfer of CSO flow would require high capacity connections to the existing pumping stations at Abbey mills, together with actuated penstocks to control the flow. An outfall tunnel and structure would be required at Charlton.

The maximum transfer rate that can be achieved is approximately 40m^3/s which is in excess of the peak output of Station F. If this capacity is exceeded CSO spill to the River Lee will be necessary to avoid upstream flooding. In theory the peak combined output of Station A and Station F could be 48m^3/s. In reality this combined peak has rarely occurred and therefore 40m3/s transfer capacity, combined with the nominal storage volume of the tunnel, should be sufficient to avoid discharge to the River Lee. As the maximum output of Station F is 32m^3/s connection of the outlet from Station A to the tunnel may also be required. However as the Station A pumping plant is older it is unlikely that this existing plant would match the output head at the required rate.

It will not be possible to utilise the recently constructed screening plant at Abbey Mills as this plant is housed in open channels and chambers. The channels are at a lower elevation than the pressure output of the pumps and would overflow, releasing the pressure. It is would therefore not be possible to surcharge the tunnel to force flows through to Charlton.

As this would be an interim provision it is assumed that the overflow to the River Thames would not be subject to screening. If screening plant was deemed necessary it would have to be built at considerable elevation, either rebuilt at Abbey Mills or at Charlton to maintain the surcharge pressure in the tunnel to effect transfer. Head loss through the plant would significantly restrict the transfer capacity, to approximately 25m^3/s. It would not be possible to transfer all CSO flow from Abbey Mills and a significant number would still result in discharge Abbey Mills to the River Lee. Upon completion to full scheme the screening plant would be come redundant.

As the tunnel would be an inverted siphon flow will accumulate, which would be pumped out to the river at Charlton. There are no treatment implications associated with this phased option as there is no additional flow passed to the treatment works.

It is only possible to effect full transfer of Abbey Mills flows if screening plant is not incorporating into this early phase option. Abbey Mills discharges would be simply be transferred from the River Lee to the River Thames at Charlton, therefore there is no reduction in discharge to the Tideway. This early phase option can only be an interim provision in advance of completion to the full option.

3.9.6.2.2 Abbey Mills to Charlton (at 7.2m diameter) and Charlton to Beckton (at 7.2m diameter)

The second potential option for early implementation incorporates more storage volume (approximately 420,000m^3), but this is still exceeded by most Abbey Mills CSO spill events and would only provide nominal attenuation to reduce peak flows. Therefore this option would be used to transfer a significant proportion of Abbey Mills CSO discharge away from the River Lee direct to the River Thames at Beckton. Once again the hydraulic capacity of the partial tunnel system is the critical factor for reduction of the frequency of spill from Abbey Mills.

Transfer of CSO flow would again require high capacity connections to the existing pumping stations at Abbey mills, together with actuated penstocks to control the flow. However to effect discharge to the River Thames at Beckton a large diameter overflow tunnel (5m diameter and approximately 1.3km long) between the main shaft and the outfall would be required as the existing storm overflow barrels would not have sufficient capacity and to exclude potential surcharge effects on the inlet works.

Although this potential early phase is the same diameter as the previous the maximum transfer rate is less at 28m^3/s due to the increased overall length of tunnel. However this transfer rate is only little below the maximum output of Station F. Therefore in conjunction with the storage volume of the tunnel section, full transfer of all Abbey Mills CSO flows may be possible. This will require detail modelling to confirm.

For the reasons described above the existing screening plant at Abbey Mills cannot be incorporated into the transfer of Abbey Mills CSO discharges.

As this would be an interim provision it is again assumed that the overflow to the River Thames would not be subject to screening. Again if screening of the flow is deemed necessary it would have to be built at high elevation to facilitate surcharge of the tunnel. The head loss imposed by the screening plant will severely restrict transfer of flow, to approximately 17m^3/s, this would result in a high frequency of discharge from Abbey Mills to the River Lee to prevent upstream flooding. Upon completion to the full scheme the screening plant would become redundant

In order to maintain the surcharge on the tunnel, the main shaft at Charlton would also be surcharged to several metres above ground. It would be necessary to isolate the Charlton CSO from this shaft when it is surcharged. Therefore if the isolation penstock failed open then the transfer of flow from Abbey Mills could not be invoked and discharge would revert to the River Lee. This risk alone is sufficient justification for not incorporating interception of the Charlton CSO in this interim provision.

However, when the system is completed to the full option this operational risk will be re-introduced as described above.

3.9.6.2.3 Summary of Early Phase Options

Early Phase Option	Storage (m^3)	Peak Transfer (m^3/s)	Comment
Abbey Mills to Charlton - unscreened	256,000	40	Elimination of discharge to River Lee, all transferred to the Thames
Abbey Mills to Charlton - screened		25	Frequent discharge from Abbey Mills to River Lee
Abbey Mills to Beckton via Charlton - unscreened	420,000	28	Possible elimination of discharge to the River Lee
Abbey Mills to Beckton via Charlton - screened		17	Very frequent discharge from Abbey Mills to River Lee

3.10 Assessment of Option 1b

3.10.1 Capital Cost

The overall capital costs for this option are summarised below:

Item	Cost (£M)
Tunnels, Shafts and CSO Interception works	1,163
Pumping, Electrical and Power Plant	119
Treatment Works for Tunnel Draindown	138
Risk & Contingency	308
Land and Compensation Costs	50
Resource costs for management and design, specialist consultancy	243
Total Cost for option	**2,021**

3.10.2 Operational Costs

The overall operational costs for this option are summarised below:

Item	Cost (£M)
Routine inspection and maintenance	1.49
Energy (pumping and ventilation)	3.71
Treatment of Tunnel Pump-out	1.83
Total Cost for option	**7.03**

3.10.3 Programme

Implementation of the complete option would require the full planning process and land acquisition, therefore the duration of pre-construction activities are judged to be approximately 52 months, or 60 months time contingency. Similar to Option 1a there are two options for implementation of early phases, however both rely on acquisition of the Charlton site for this main shaft, therefore a similar duration for pre-construction activities is considered appropriate

The Abbey Mills to Beckton, via Charlton early phase only takes marginally longer to construct as the two tunnel legs are carried out simultaneously.

Option 1a	Start Date	Pre-construction Phase	Construction Start Date	Construction	Completion Date
Complete Option	March 2007	60 months (52 months)	Feb 2012 (Jul 2011)	92 months (84 months)	Oct 2019 (Jul 2018)
Either Early Phase	January 2007	60 months 52 months	Nov 2011 (May 2011)	58 months (53 months)	Oct 2016 (Nov 2015)

The main dates and durations quoted include a 15% time contingency for the pre-construction activities and a 10% contingency for construction. The figures in brackets exclude this contingency and represent the earliest dates and shortest durations

The compulsory purchase process determines that the early phases cannot be implemented in time for the Olympics even without invoking the time contingency periods

3.10.4 Construction and Constructability

The construction methods are generally as described before. The logistics of construction for the complete option and the early phased option would be very similar to that described for Option 1a as the routes and locations are identical.

3.10.5 Key Issues and risk

As for Option 1a the surcharge of Charlton main shaft to invoke transfer of CSO flows from Abbey Mills is the key risk. Similarly therefore the transfer of Abbey Mills flows to discharge at Beckton for either the early phases or the complete option is not recommended.

3.10.6 Interception Performance

3.10.6.1 Complete Solution

The complete solution has a storage volume of approximately 1,155,000m^3 which acts in combination with the increased flow to full treatment at Beckton STW of 2,105Mld. The overall capacity for this option is less than Option 1a. Therefore the modelling results showed an increase in frequency of bypass as follows:

Bypass Frequency (Spill Day Events)		Typical Annual Volumes (m^3)		
Average	Typical Year	Bypass	Interception to tunnel	Interception Direct to Treatment
9	3	2,311,479	37,749,623	8,062,263

This system would be able to completely intercept all events except approximately 9 per year on average. For these events that exceed the system capacity, a volume equivalent to the tunnel storage volume will at least be intercepted thus significantly reducing the volume of discharge. Furthermore most of the first flush of the discharge will be intercepted, which would significantly reduce the polluting load.

The increased interception to 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 that the volume of the tunnel, more flow is passed to the tunnel for this option

In order to maintain the ability to transfer all Abbey Mills, that is to reduce discharge to the River Lee, the tunnel legs from Abbey Mills to Charlton to Beckton would have to be surcharged by the Station F pumps as described for Abbey Mills Transfer.

In order to maintain the surcharge on this tunnel section it would have to be isolated from the remainder of the main tunnel and the Charlton CSO connection by penstocks in the main shaft at Charlton.

Therefore if the isolation penstock failed open then the transfer of flow from Abbey Mills could not be invoked and discharge would revert to the River Lee. This is only possible when the capacity of the system is exceeded, potentially 9 times per year.

3.10.6.2 Early Phases

3.10.6.2.1 Abbey Mills to Charlton (at 6m diameter)

The potential application of the first option is similar to for Option 1a, however the peak transfer capacity is much reduced. The storage volume afforded by this leg of the tunnel is approximately 166,00m^3, which is relatively insignificant compared with the volumes discharged from Abbey Mills and would provide insignificant attenuation. The hydraulic capacity is therefore the critical factor for reducing discharge from Abbey Mills to the River Lee.

The maximum transfer rate is approximately 30m^3/s which is less than the peak output of Station F. Therefore for larger events some discharge to the River Lee will be necessary to prevent upstream flooding. If screening plant is included the peak transfer rate would reduce to 14m^3/s. This rate would be exceeded by many events resulting in frequent discharge to the River Lee.

To effect this transfer it is necessary to surcharge the tunnel therefore, for the reasons described for Option 1a, it will not be possible to utilise the recently constructed screening plant at Abbey Mills as part of this interim system. If screening plant is deemed necessary it would have to be constructed at elevation to maintain the hydraulic pressure for surcharge of the tunnel against high tide.

As the tunnel would be an inverted siphon flow will accumulate, which would be pumped out to the river at Charlton. There are no treatment implications associated with this phased option as there is no additional flow passed to the treatment works.

With this early phase option it is only possible to effect partial transfer of Abbey Mills flows if screening plant is not incorporated into this early phase option. As most of the Abbey Mills discharges would be simply be transferred from the River Lee to the River Thames at Charlton, there is no actual reduction in discharge to the Tideway. This early phase option can only be an interim provision in advance of completion to the full option.

3.10.6.2.2 Abbey Mills to Charlton (at 6m diameter) and Charlton to Beckton (at 6m diameter)

The second potential option for early implementation is very similar to that of Option 1a, but as it is only 6m in diameter it incorporates reduced storage volume (approximately 308,000m^3) and will be exceeded by most Abbey Mills CSO spill events.

Again the hydraulic capacity of the partial tunnel system is still the critical factor in for determination of the frequency of spill from Abbey Mills. The maximum transfer rate is reduced to 21m^3/s, due to the longer length of tunnel and the restriction of the overflow tunnel. This capacity will be frequently exceeded resulting in CSO spill from Abbey Mills to the River Lee. Implementation of screening would further reduce transfer capacity to approximately 12m^3/s

Transfer of CSO flow would again require high capacity connections to the existing pumping stations at Abbey mills, together with actuated penstocks to control the flow and a large diameter overflow tunnel at Beckton.

As for Option 1a the Charlton shaft will be subject to regular surcharge. Therefore, for the operational risks described before it is not justified to connect the Charlton CSO to this interim provision.

However, when the system is completed to the full option this operational risk will be reintroduced as described above.

3.10.6.2.3 Summary of Early Phase Options

Early Phase Option 1b	Storage (m^3)	Peak Transfer (m^3/s)	Comment
Abbey Mills to Charlton - unscreened	166,000	30	Infrequent discharge from Abbey Mills, most transferred to the Thames
Abbey Mills to Charlton - screened		14	Frequent discharge from Abbey Mills
Abbey Mills to Beckton via Charlton - unscreened	308,000	21	Fairly frequent discharge from Abbey Mills
Abbey Mills to Beckton via Charlton - screened		12	Very frequent discharge from Abbey Mills

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3.11 Assessment of Option 1c

3.11.1 Capital Cost

The overall capital costs for this option are summarised below:

Item	Cost (£M)
Tunnels, Shafts and CSO Interception works	1,234
Pumping, Electrical and Power Plant	131
Treatment Works for Tunnel Draindown	145
Risk & Contingency	309
Land and Compensation Costs	50
Resource costs for management and design, specialist consultancy	259
Total Cost for option	**2,128**

If this option is implemented in phases, with the east tunnel leg constructed as an early first phase, including the full extension of the treatment works, completed before the Olympic period, then followed immediately by the completion to the full scheme, the costs become:

Item	Total Cost (£M)
First phase of Option 1c	**619**
Total costs upon completion	**2,160**

The overall increase in cost is due to remobilisation costs and extended duration of construction.

3.11.2 Operational Costs

The overall operational costs for this complete option are summarised below:

Item	Cost (£M)
Routine inspection and maintenance	1.52
Energy (pumping and ventilation)	3.47
Treatment of Tunnel Pump-out	2.19
Total Cost for option	**7.18**

3.11.3 Programme

Implementation of the complete option would require the full planning process and land acquisition, therefore the duration of pre-construction activities are judged to be approximately 52 months, or 60 months including time contingency.

There is one option for implementation of an early phase, construction of the tunnel leg between Abbey Mills and Beckton.

Option 1c	Start Date	Pre-construction Phase	Construction Start Date	Construction	Completion Date
Complete Option	March 2007	60months (52 months)	Feb 2012 (Jul 2011)	96 months (87 months)	Jan 2020 (Oct 2018)
Early Phase	January 2007	18 months	July 2008	46 months (45 months)	April 2012 (March 2012)
Phased Completion	March 2007	60months (52 months)	Sept 2012	92 months (84 months)	Apr 2020 (Sept 2019)

The main dates and durations quoted include a 15% time contingency for the pre-construction activities and a 10% contingency for construction. The figures in brackets exclude this contingency and represent the earliest dates and shortest durations

For the early phase both sites are owned by TW, so there are no issues associated with land acquisition. There is limited tunnelling under third party land that could be carried out subject to Notice under the Water Industry Act and the extent of the works is all contained within one London Borough. In consideration of these advantageous factors a foreshortened programme of pre-construction activities is therefore considered appropriate.

For this option the earlier start date of January 2007 has been assumed because of the perceived potential urgency to complete these works before the Olympic period. Only a nominal time contingency allowance is included, as the end date is assumed to be fixed and there are options based on partial completion of the works to ensure sufficient completion prior to the Olympic period to recover time lost due to construction difficulties.

Achievement of this accelerated programme requires a prompt ministerial decision to proceed in January 2007. It also requires remediation works at Beckton STW to be carried out in advance of planning permission.

If this accelerated programme for the pre-construction activities is not invoked and the more extensive processes followed, construction start would be delayed to July 2011 and completion of this first phase would not be until March 2015 at the earliest. These target dates would be pushed back to a construction start of December 2011 and completion of March 2016 if the full time contingency periods were invoked.

Subject to an immediate Ministerial decision, the early phase of Option 1c is the only option that can be implemented in time for the Olympics.

Phased completion of the scheme will be reliant upon acquisition of the sites for the main shafts, most likely by compulsory purchase. It is also assumed that the full planning process may be required as it will involve several London Boroughs and many stakeholders. Whilst this process could be completed by July 2011, or February 2012 with time contingency the construction of the second phase has been assumed to start immediately after the Olympics in September 2012 to avoid any major works during the Olympic period.

3.11.4 Construction and Constructability

The construction methods are generally as described before. The main drive shafts would be Heathwall, Charlton and Beckton for the full option. For the early implementation of the first phase the main drive shaft would be at Beckton. A significant quantity of the material excavated from this tunnel drive could be utilised as engineering fill to the Beckton Rectangle in preparation of the remainder of the site for re-development.

3.11.5 Key Issues and risk

The early implementation of the Abbey Mills to Beckton tunnel length is the only first phase option that can be implemented before the Olympic period. However there is little time contingency therefore the decision to proceed must be made in January 2007.

For the early phase option there is no operation of isolating penstocks required to effect the transfer of Abbey Mills flows to Beckton as there are no connections to other CSOs. Therefore there is no risk associated with localised flooding or abandoning the transfer due to a malfunction.

Upon completion to the full scheme an isolating penstock will be required in the Beckton Overflow shaft to isolate the main tunnel from the Abbey Mills to Beckton length during transfer of Abbey Mills CSO flows. This operational intervention will only be required when the system capacity is exceeded, approximately three times per year. If this penstock fails to close the transfer would have to be abandoned and discharge to the River Lee would result.

The pumping station and overflow shafts at Beckton will have to be extended above ground to facilitate the surcharge conditions for the Abbey Mills Surcharge. However there is no risk of localised flooding local ground levels can be built up to that of the surrounding area.

The proposed accelerated programme for the early phase option entails a potential risk of lack of resource availability due to competing projects. The general mitigation being that it is likely that European staff and resources can be employed

Again due to the competition for of other projects associated with development of the Olympic Park there may be a significant price escalation within the supply chain that may be in excess of the construction inflation indexes.

3.11.6 Interception Performance

3.11.6.1 Complete Solution

The complete solution has a storage volume of approximately 1,638,000m^3 which acts in combination with the increased flow to full treatment at Beckton STW of 2,336Mld. Modelling results show that the interception performance in terms of average flows is as follows:

Bypass Frequency (Spill Day Events)		Typical Annual Volumes (m^3)		
Average	Typical Year	Bypass	Interception to tunnel	Interception Direct to Treatment
3-4	1	993,171	35,977,253	11,278,622

As this option has a slightly larger storage volume, it intercepts marginally more flow to the tunnel than Option 1a, resulting in slightly less bypass volume to the river.

Similar to Option 1a, this system would be able to completely intercept all events except approximately 3 per year on average. For these events that exceed the system capacity, a volume equivalent to the tunnel storage volume will at least be intercepted thus significantly reducing the volume of discharge. Furthermore the first flush of the discharge will be intercepted, which would significantly reduce the polluting load.

In order to maintain the ability to transfer all Abbey Mills, that is to eliminate discharge to the River Lee, the tunnel legs from Abbey Mills to Charlton to Beckton would have to be surcharged by the Station F pumps as described for Abbey Mills Transfer. The transfer capacity will be as described for the early phase option and will be sufficient to transfer the excess Abbey Mills CSO flows for bypass at Beckton when the overall capacity is exceeded.

In order to maintain the surcharge on this tunnel section it would have to be isolated from the remainder of the main tunnel by a penstock in the Beckton Overflow. Therefore if the isolation penstock failed open then the transfer of flow from Abbey Mills could not be invoked and discharge would revert to the River Lee. For the complete option this is only possible when the capacity of the system is exceeded, potentially three times per year.

3.11.6.2 Early Phase

The potential application of the early implementation of the eastern section of the tunnel system, namely the Abbey Mills to Beckton leg at 7.2m diameter, would be to transfer Abbey Mills CSO discharge away from the River Lee direct to the River Thames at Beckton. The existing pumping plant at Abbey Mills could be utilised to surcharge this leg of the tunnel and force flow into the River Thames against high tide.

The storage volume afforded by this leg of the tunnel is approximately 276,00m^3. During 2004 over 35 events exceeded this volume of discharge, therefore it is relatively insignificant compared with the volumes discharged from Abbey Mills and only provides nominal attenuation.

However if the capacity of Beckton STW is increased to that required for the full tunnel, a significant portion of the discharge could also be transferred to treatment either direct via increasing flows in the NOS or indirectly via pump-out from the tunnel. This could reduce the number of times the combined capacity of the tunnel and treatment works is exceeded and hence bypass to the River Thames to a frequency of about 8 times per year.

Transfer of CSO flow would require high capacity connections to the existing pumping station at Abbey mills, together with actuated penstocks to control the flow. However to effect discharge/bypass to the River Thames at Beckton a large diameter overflow tunnel (5m diameter and approximately 1.3km long) between the main shaft and the existing outfall would be required as the existing storm overflow barrels would not have sufficient capacity. This approach would also exclude potential surcharge effects on the inlet works.

The maximum transfer rate that can be achieved is approximately 31m^3/s which is approximately equal to the theoretical maximum output of Station F. Although this capacity is less than the theoretical peak combined output of Station A and Station F together of 48m^3/s, in reality this combined peak has rarely occurred. Therefore 31m^3/s transfer capacity, combined with the nominal storage volume of the tunnel and the increase of flow transfer through the NOS to treatment should be sufficient to avoid discharge to the River Lee.

As this would be an interim provision, pending completion to the full scheme, it is assumed that the overflow to the River Thames would not be subject to screening. Screening plant would severely restrict the transfer capacity, to approximately 19m^3/s. This would result in unavoidable CSO spill from Abbey Mills to the River Lee to avoid upstream flooding.

3.11.6.3 Summary of Early Phase Option

Early Phase Option	Storage (m^3)	Peak Transfer (m^3/s)	Comment
Abbey Mills to Beckton - unscreened	276,000	31	Elimination of discharge to River Lee, all transferred to the Thames
Abbey Mills to Beckton - screened		19	Frequent discharge from Abbey Mills to River Lee

3.12 Assessment of Option 2a

3.12.1 Capital Cost

The overall costs for this option are summarised below:

Item	Cost (£M)
Tunnels, Shafts and CSO Interception works	910
Pumping, Electrical and Power Plant	136
Treatment Works for Tunnel Draindown	114
Risk & Contingency	264
Land and Compensation Costs	40
Resource costs for management and design, specialist consultancy	198
Total Cost for option	**1,662**

3.12.2 Operational Costs

The overall operational costs for this option are summarised below:

Item	Cost (£M)
Routine inspection and maintenance	1.43
Energy (pumping and ventilation)	3.51
Treatment of Tunnel Pump-out	1.39
Total Cost for option	**6.33**

3.12.3 Programme

Implementation of the complete option would require the full planning process and land acquisition, therefore the duration of pre-construction activities are judged to be approximately 52 months. For the implementation of the complete option it is assumed that the east and west tunnels would be constructed separately but in parallel. Therefore the overall delivery will be governed by the longest programme, which is for the west tunnel.

There is only one option for implementation of an early phase, which is the east tunnel, constructed between Abbey Mills and Beckton, constructed separately and in advance.

Option 2a	Start Date	Pre-construction Phase	Construction Start Date	Construction	Completion Date
Complete Option	March 2007	60 months (52 months)	Feb 2012 (Jul 2011)	85 months (77 months)	Feb 2019 (Nov 2017)
Early Phase	January 2007	18 months	July 2008	71 months	May 2014

The main dates and durations quoted include a 15% time contingency for the pre-construction activities and a 10% contingency for construction. The figures in brackets exclude this contingency and represent the earliest dates and shortest durations

For the early phase option, both sites for the main shafts are owned by TW, so there are no issues associated with land acquisition. There is limited tunnelling under third party land that would be subject to Notice under the Water Industry Act. The extent of the works is all contained within one London Borough. Therefore a foreshortened programme of pre-construction activities is considered appropriate and with an earlier start date of January 2007, to reflect the perceived urgency, a construction start date of July 2008 would be possible. The duration of construction is estimated from the full programme. However even incorporating a foreshortened period for pre-construction activities this option would overshoot the Olympic period by nearly two years.

3.12.4 Construction and Constructability

The construction methods are generally as described before. The drive shaft for the west tunnel would be at Heathwall and for the east tunnel the drive will be from Beckton.

The process of launching the 13m diameter TBM for the east tunnel from the deep shaft at Beckton will incur significant engineering challenge, due to the depth, overall size and groundwater pressures. There is little, if any, experience of carrying out such a large TBM launch in this manner and under these conditions as such large tunnels are normally associated with transportation projects and therefore driven from portal structures close to ground level.

The launch procedure is very likely to require the construction of significant underground launch chambers to facilitate TBM assembly. Construction of these chambers is likely to be by the NATM method and excavation of these chambers would potentially involve large areas of unsupported ground during the construction sequence which would require extensive geotechnical works to seal and support potential fractures in the Chalk strata. The advance construction of a smaller diameter adit or exploratory tunnel from the shaft may also be prudent to establish the competency of the Chalk and determine the full extent of the geotechnical works to stabilise the ground for excavation of the launch chamber.

It has also been established that the ground movements associated with the construction of the east tunnel would generate unacceptable deformations of the EDF Cable Tunnels near Abbey Mills. These cable tunnels are currently under construction, however it is generally considered too late to incorporate strengthening measures in their structure. Upon completion the tunnels will house high voltage cables and a mini railway (for inspection purposes) and will not therefore be amenable to retrofitting of strengthening works. The impact of the ground movements on existing railway track is also likely to be significant.

3.12.5 Key Issues and Risks

The particular concern is the launching and recovery of the TBM for the east tunnel as described above. There is great potential for delay in carrying out the works necessary to launch the TBM. For obvious reasons this option cannot be recommended as an early phase for implementation.

The potential impact on the EDF Cable Tunnels is significant and, as yet, there is no measure identified to mitigate the inevitable damage to these tunnels. The potential impact on the railway track is significant and will inevitably cause delay and disruption to rail traffic, however the damage can be rectified by re-grading the tracks once the settlement has occurred.

There is also considerable uncertainty around the construction of the wet-well and dry-well shafts for the pumping station on the west tunnel at Heathwall. Additional land to the west of Heathwall PS would have to be acquired to accommodate these shafts. It is likely that such a large proportion of the Tideway Industrial Estate would have to be acquired as to make the residual uneconomic for retention by the current owners.

The site to the west of Heathwall PS is in fact where the original Heathwall PS was located. Therefore a considerable extent of obstructions would have to be overcome for the construction of the shafts. Whilst some allowance for the cost and delay of such obstructions has been anticipated in the budget costs and programme, there is nevertheless likely to be additional cost and delay.

There are also serious operational issues with the pump-out regime from the west tunnel, which 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.

3.12.6 Interception Performance

3.12.6.1 Complete Solution

The east tunnel has a storage volume of approximately 769,000m^3 which acts in combination with the increased FFT at Beckton STW of 1,998Mld. The west tunnel has a storage volume of 492,000m^3. The interception capacity the west tunnel cannot include any additional capacity at the sewage treatment works as the tunnel is isolated from the works and the existing interceptor sewer system will be full to maximum capacity during an event.

Modelling results show that the interception performance in terms of average and typical flows is as follows:

Bypass Frequency (Spill Day Events)		Typical Annual Volumes (m^3)			
Average	Typical Year	Bypass	Interception to tunnel	Interception Direct to Treatment	Spill from un-connected CSOs
2 - 9	2	904,157	22,017,164	9,802,174	10,113,158

The bypass frequency for Options 2a – 2c is quoted for the CSOs connected to the tunnel lengths. However these options do not intercept 16 category 1 and 2 CSOs in the central area, therefore these CSOs would continue to discharge unimpeded. **Therefore in overall terms there is no reduction in spill day events.**

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

3.12.6.2 Early Phase & Abbey Mills Transfer

The only option for early implementation is the advance construction of the east tunnel. This tunnel would reduce the frequency of bypass from Abbey Mills to the River Lee to approximately 3 per year. Upon provision of high capacity connections to the existing pumping stations and flow control arrangements at Abbey Mills, together with the overflow tunnel and outfall at Beckton, the tunnel system should have ample hydraulic capacity to transfer all CSO flow to discharge at Beckton. The transfer of Abbey Mills CSO flows to bypass at Beckton would be invoked in exactly the same fashion for the complete option.

However the diameter of the overflow tunnel is limited by space constraints at the outfall end it would impose a significant head loss at high flows. The outfall tunnel becomes the hydraulic control and limits transfer capacity to approximately 37m^3/s, but taken in combination with significant attenuation in the tunnel CSO spill at Abbey Mills would be avoided.

It is assumed that the overflow to the River Thames would not be subject to screening as this would be an interim provision. If screening of the flow is deemed necessary the head loss imposed by the screening plant will impose a restriction on the maximum rate of transfer. It is likely to reduce to approximately 29m^3/s. Taken with the attenuation in the tunnel this may be sufficient to avoid CSO spill at Abbey Mills but requires confirmation by more detailed analysis. The value of providing such screening plant is questionable as it would only be used infrequently and is therefore unlikely to be reliable. It would also treat a relatively small volume of flow at the peak of the event.

3.13 ASSESSMENT OF OPTION 2B

3.13.1 Capital Cost

The overall costs for this option are summarised below:

Item	Cost (£M)
Tunnels, Shafts and CSO Interception works	859
Pumping, Electrical and Power Plant	131
Treatment Works	204
Risk & Contingency	264
Land and Compensation Costs	40
Resource costs for management and design, specialist consultancy	187
Total Cost for option	**1,685**

3.13.2 Operational Costs

The overall operational costs for this option are summarised below:

Item	Cost (£M)
Routine inspection and maintenance	1.54
Energy (pumping and ventilation)	3.09
Treatment of Tunnel Pump-out	2.68
Total Cost for option	**7.31**

3.13.3 Programme

Implementation of the complete option would require the full planning process and land acquisition, therefore the duration of pre-construction activities are judged to be approximately 52 months. For the implementation of the complete option it is assumed that the east and west tunnels would be constructed separately but in parallel. Therefore the overall delivery will be governed by the longest programme, which is for the west tunnel.

There is only one option for implementation of an early phase, which is the 10m diameter east tunnel, between Abbey Mills and Beckton, constructed separately and in advance.

Option 2b	Start Date	Pre-construction Phase	Construction Start Date	Construction	Completion Date
Complete Option	March 2007	60 months (52 months)	Feb 2012 (Jul 2011)	85 months (77 months)	Feb 2019 (Nov 2017)
Early Phase	January 2007	18 months	July 2008	71 months	May 2014

The main dates and durations quoted include a 15% time contingency for the pre-construction activities and a 10% contingency for construction. The figures in brackets exclude this contingency and represent the earliest dates and shortest durations

For the early phase option, both sites for the main shafts are owned by TW, so there are no issues associated with land acquisition. There is limited tunnelling under third party land that would be subject to Notice under the Water Industry Act. The extent of the works is all contained within one London Borough. Therefore a foreshortened programme of pre-construction activities is considered appropriate and with an earlier start date of January 2007, to reflect the perceived urgency, a construction start date of July 2008 would be possible. The duration of construction is estimated from the full programme. It should be noted that construction of the 10m diameter tunnel would only be marginally quicker that the 13m diameter tunnel of Option 2a. However even incorporating a foreshortened period for pre-construction activities this option would overshoot the Olympic period by nearly two years.

3.13.4 Construction and Constructability

The construction methods are generally as described before. The drive shaft for the west tunnel would be at Heathwall and for the east tunnel the drive will be from Beckton.

The process of launching the 10m diameter TBM for the east tunnel from the deep shaft at Beckton will incur significant engineering challenge, due to the depth, overall size and groundwater pressures. Similar to the requirements for the 13m diameter, it is likely that the launch procedure would require the construction of significant underground chambers to facilitate TBM assembly and therefore similar risks will be incurred.

It has also been established that the ground movements associated with the construction of the east tunnel at 10m diameter may generate significant deformations of the EDF Cable Tunnels near Abbey Mills. As before there is no opportunity to include strengthening measures in their structure. The constraints of retrofitting of strengthening works upon completion of the tunnels are the same. The impact of the ground movements on existing railway track is also likely to be significant.

3.13.5 Key Issues and Risks

The particular concern is the launching and recovery of the TBM for the east tunnel as described above. There is significant potential for delay in carrying out the works necessary to launch the TBM. For obvious reasons this option cannot be recommended as an early phase for implementation.

Similar to Option 2a, the potential impact on the EDF Cable Tunnels is significant and, as yet, there is no measure identified to mitigate the damage to these tunnels. The potential impact on the railway track is also significant and will inevitably cause delay and disruption to rail traffic, however the damage can be rectified by re-grading the tracks once the settlement has occurred.

The proposed works for the west tunnel are identical to that of Option 2a, therefore the considerable uncertainty around the construction of the wet-well and dry-well shafts for the pumping station, the land acquisition issues and potential extent of underground obstructions are the same. The risks and issues associated with the pump-out regime are identical

3.13.6 Interception Performance

3.13.6.1 Complete Solution

The east tunnel has a storage volume of approximately 455,000m^3 which acts in combination with the increased FFT at Beckton STW of 2,700Mld. The west tunnel has a storage volume of 492,000m^3. The interception capacity the west tunnel cannot include any additional capacity at the sewage treatment works as the tunnel is isolated from the works and the existing interceptor sewer system will be full to maximum capacity during an event.

Modelling results show that the interception performance in terms of average and typical flows is as follows:

Bypass Frequency (Spill Day Events)		Typical Annual Volumes (m^3)			
Average	Typical Year	Bypass	Interception to tunnel	Interception Direct to Treatment	Spill from un-connected CSOs
2 - 9	5	1,559,284	12,009,917	19,134,742	10,774,115

The bypass frequency for this option is quoted for the CSOs connected to the tunnel lengths. However this option does not intercept 16 category 1 and 2 CSOs in the central area, therefore these CSOs would continue to discharge unimpeded. **Therefore in overall terms there is no reduction in spill day events.**

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

3.13.6.2 Early Phase & Abbey Mills Transfer

Similar to Option 2a, the only option for early implementation is the advance construction of the east tunnel. The eastern tunnel in combination with the increased FFT of 2,700Mld at Beckton would reduce the frequency of bypass from Abbey Mills to the River Lee to approximately 5 per year. In conjunction with the high capacity connections to Station F and the overflow tunnel and outfall at Beckton these excess CSO flows can be transferred from Abbey Mills to discharge at Beckton

The peak transfer capacity would be approximately $36m^3/s$, which taken in combination with significant attenuation in the tunnel CSO spill at Abbey Mills would be avoided. If screening of the flow is deemed necessary the peak transfer rate is likely to reduce to approximately $23m^3/s$. Taken with the attenuation in the tunnel this may be sufficient to avoid CSO spill at Abbey Mills but requires confirmation by more detailed analysis.

3.14 Assessment of Option 2c

3.14.1 Capital Cost

The overall costs for this option are summarised below:

Item	Cost (£M)
Tunnels, Shafts and CSO Interception works	970
Pumping, Electrical and Power Plant	139
Treatment Works for Tunnel Draindown	114
Risk & Contingency	264
Land and Compensation Costs	50
Resource costs for management and design, specialist consultancy	209
Total Cost for option	**1,746**

3.14.2 Operational Costs

The overall operational costs for this option are summarised below:

Item	Cost (£M)
Routine inspection and maintenance	1.51
Energy (pumping and ventilation)	3.51
Treatment of Tunnel Pump-out	1.39
Total Cost for option	**6.41**

3.14.3 Programme

Implementation of the complete option would require the full planning process and land acquisition, therefore the duration of pre-construction activities are judged to be approximately 52 months. For the implementation of the complete option it is assumed that the east and west tunnels would be constructed separately but in parallel. Therefore the overall delivery will be governed by the longest programme, which is for the west tunnel.

There are two options potential options for early implementation of the east tunnel sections, which are similar in concept to that described for Option 1a, however the tunnel diameters are larger and therefore incorporate more capacity:

1. Abbey Mills to Charlton at 10m diameter
2. The full east tunnel at 10m diameter, Abbey Mills to Beckton via Charlton

Both options rely on the acquisition of the Charlton site for this main shaft, therefore a similar duration of pre-construction activities is considered appropriate.

The second option does not take longer to construct as the two tunnel legs would be carried out simultaneously. Therefore there is no difference in the overall duration of the implementation programme.

Option 2c	Start Date	Pre-construction Phase	Construction Start Date	Construction	Completion Date
Complete Option	March 2007	60 months (52 months)	Feb 2012 (Jul 2011)	85 months (77 months)	Feb 2019 (Nov 2017)
Either Early Phase	January 2007	52 months	July 2011	71 months	June 2017

The main dates and durations quoted include a 15% time contingency for the pre-construction activities and a 10% contingency for construction. The figures in brackets exclude this contingency and represent the earliest dates and shortest durations

For the early implementation options an earlier start date of January 2007 has been assumed because of the perceived potential urgency to attempt completion before the Olympic period. The duration of construction is estimated from the full programme. The likely duration of the compulsory purchase process and the extended duration of the works, mainly due to the larger tunnel diameter, determines that the early phases cannot be implemented in time for the Olympics.

3.14.4 Construction and Constructability

The construction methods are generally as described before. The drive shaft for the west tunnel would be at Heathwall and for the east tunnels the drives will be from Beckton and Charlton.

The process of launching the 10m diameter TBM for the east tunnel from the deep shaft at Beckton or Charlton will incur significant engineering challenge, due to the depth, overall size and groundwater pressures. It is likely that the launch procedure would require the construction of significant underground chambers to facilitate TBM assembly and therefore similar risks will be incurred.

Although these tunnel routes avoid the EDF Cable Tunnels and railway near Abbey Mills, the Abbey Mills to Beckton leg will be subject to the more variable and less predictable ground conditions along the Lee Valley. This variability will have a greater impact on construction risk as the tunnel is larger in diameter.

3.14.5 Key Issues and Risks

The particular concern is the launching and recovery of the TBM for the east tunnel as described above. There is significant potential for delay in carrying out the works necessary to launch the TBM. For obvious reasons this option cannot be recommended as an early phase for implementation.

The particular risk of surcharge of the Charlton main shaft to invoke transfer of CSO flows from Abbey Mills is again a serious issue, similar to Option 1a. Should the isolating penstocks fail open then the main tunnel would also be surcharged resulting in backflow through upstream CSOs which would cause localised flooding. Backflow through the Charlton CSO connection would create localised flooding and restrict the capacity of Charlton storm relief, which may result in flooding further upstream. The main shaft at Charlton would also have to be extended above ground to prevent release of flow from the roof covers.

Due to this risk of potential flooding the transfer of Abbey Mills flows to discharge at Beckton for either the early phases or the complete option is not recommended

The proposed works for the west tunnel are identical to that of Option 2a, therefore the considerable uncertainty around the construction of the wet-well and dry-well shafts for the pumping station, the land acquisition issues and potential extent of underground obstructions are the same. The risks and issues associated with the pump-out regime are identical

3.14.6 Interception Performance

3.14.6.1 Complete Solution

The east tunnel has a storage volume of approximately 769,000m^3 which acts in combination with the increased FFT at Beckton STW of 1,998Mld. The west tunnel has a storage volume of 492,000m^3 . The interception capacity the west tunnel cannot include any additional capacity at the sewage treatment works as the tunnel is isolated from the works and the existing interceptor sewer system will be full to maximum capacity during an event.

Modelling results show that the interception performance in terms of average and typical flows is as follows:

Bypass Frequency (Spill Day Events)		Typical Annual Volumes (m^3)			
Average	Typical Year	Bypass	Interception to tunnel	Interception Direct to Treatment	Spill from un-connected CSOs
2 - 9	2	971,305	19,943,480	9,797,642	10,179,582

The bypass frequency for this option is quoted for the CSOs connected to the tunnel lengths. However this option does not intercept 16 category 1 and 2 CSOs in the central area, therefore these CSOs would continue to discharge unimpeded. **Therefore in overall terms there is no reduction in spill day events.**

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

3.14.6.2 Early Phase & Abbey Mills Transfer

3.14.6.2.1 Abbey Mills to Charlton at 10m diameter

The potential application of this first option would be to transfer all Abbey Mills CSO discharge away from the River Lee to The River Thames at Charlton. The existing plant at Abbey Mills could be utilised to surcharge the tunnel and force flow into the River Thames against high tide.

The storage volume provided by this tunnel, approximately 445,000m^3 is reasonable and would afford some attenuation of peak flow rate. The potential maximum transfer would be 50m^3/s (which is in excess of current pumping capacity), reduced to 33m^3/s if screening plant is introduced. It is likely that in either case transfer of all Abbey Mills CSO flow to Charlton would be possible, subject to confirmation by more detailed analysis.

Upon completion to the full scheme the screening plant at Charlton would become redundant. As this phased option would be an interim arrangement the value of providing the screening plant at Charlton is questionable.

There are no treatment implications associated with this phased option as all flow, including that retained in the tunnel would be passed direct to the river.

3.14.6.2.2 Full eastern tunnel at 10m diameter

The peak transfer capacity would be approximately 35m^3/s, which taken in combination with significant attenuation in the tunnel CSO spill at Abbey Mills would be avoided. If screening of the flow is deemed necessary the peak transfer rate is likely to reduce to approximately

$23m^3/s$. Taken with the attenuation in the tunnel this may be sufficient to avoid CSO spill at Abbey Mills but requires confirmation by more detailed analysis.

4 COMPARISON OF OPTIONS

4.1 FULL TUNNEL OPTIONS

Options 1a, 1b and 1c intercept all category 1 and 2 CSOs. Although the storage volume provided by the 6m diameter tunnel of Option 1b is significantly smaller, only 70% of Options 1a and 1c, the estimated cost decreases by only 4%. The disproportionate cost difference arises because the common costs associated with these options, such as the CSO interception works and main shaft are quite high. There is in fact only a slight reduction in the cost for the pumping plant and additional treatment plant. The cost difference between the 7.2m diameter and 6.0m diameter tunnelling works is only approximately £50M

Implementation of Option 1b would provide significantly lower interception performance resulting in a threefold increase in bypass frequency for a relatively insignificant cost saving.

Option 1c involves a slightly longer total length of main tunnel, compared with Option 1b, hence the 1.7% increase in budget estimate. However the Abbey Mills to Beckton section of Option 1c is the only early first phase of any option that can be implemented before the Olympic period.

4.2 PARTIAL TUNNEL OPTIONS

The comparison of Options 2a and 2b shows the implication of providing more treatment capacity to compensate for a lower storage provision. For the east tunnel of Option 2a the tunnel volume was sized to reduce the bypass frequency to approximately 3 per year. The associated treatment extension was required only to deal with tunnel pump-out. For Option 2b the tunnel diameter and therefore storage volume was reduced, however the FFT at Beckton STW was increased to the maximum rate that could be accommodated by the existing inlet works and primary sedimentation tanks. In effect it was only necessary to increase the provision of secondary treatment and final sedimentation plant.

The overall budget cost for Option 2b is marginally greater than 2a and operational costs are significantly higher. However the interception performance is not as good. Option 2b would require a larger increase in treatment capacity to match the interception performance of 2a. This would imply a step change in the cost of treatment plant as any further increase would require extensions to the inlet works and primary tanks as well. The conclusion is that additional treatment capacity is a more expensive form of acquiring interception performance.

The comparison between the east tunnel of Options 2a and 2c shows that provision of storage volume is more expensive utilising a longer length of smaller diameter tunnel.

4.3 FULL AND PARTIAL TUNNEL OPTIONS

The general comparison between Options 1a/1c and Options 2a/2c shows there is a significant difference in cost, approximately 20%. However Options 1a/1c intercept all category 1 and 2 CSOs and only allow approximately $1Mm^3$ bypass to the river per year. On the other hand Options 2a/2c do not intercept 16 category 1 and 2 CSOs in the central section, which will continue to discharge unimpeded with the same frequency and volume of spill. Options 2a/2c will allow a bypass of approximately $11Mm^3$ per year and do not comply with the DO standards for sustainable fish populations.

4.4 EARLY IMPLEMENTATION OPTIONS

All options have potential first phases for early implementation, however only the east section of Option 1c, the tunnel section between Abbey Mills and Beckton can be implemented before the Olympic period.

5 PRINCIPAL CONSIDERATIONS

5.1 Process Arisings Strategy

It is proposed to transport the excavated material, or process arisings, from the main tunnel by river barges. Temporary jetties or extensions to existing jetties would be provided to accommodate this process. The scope and budget estimates for each option includes for disposal of the excavated material to landfill and therefore includes an allowance for Landfill Tax.

In fact there are many potential uses for the material including engineering fill to prepare brownfield sites for redevelopment, capping of fill sites and pipeline backfill. In particular the opportunity to use the process arisings from the construction of the first phase of Option 1c as engineering fill on the Beckton Rectangle could be quite advantageous in terms of cost and time.

Many of these options for use of the process arisings may save cost and improve the environmental credibility of the scheme. However the viability of these options is dependent on the proposed programme since potential sites to accommodate materials need to be available at the appropriate time.

5.2 Ground Movements

The potential impact of ground movements associated with construction of the main tunnel was considered as part of the TTSS. This involved a thorough high-level assessment of the likely ground movements and the potential impact on bridges, river embankment walls and other tunnels that the proposed main storage tunnel would pass under along the route following the Thames.

This assessment was based on a nominal 9m internal diameter tunnel. The results were encouraging as, due to the depth of the main tunnel, the potential impact by way of settlement and induced strain and deformation, was established to be nominal or negligible.

For current options, where the tunnel route follows the Thames, the potential main tunnel diameters are now smaller therefore the potential impact is further reduced. The 7.2m, 6.0m and 7.6m diameter tunnels of Options 1a/1c, 1b and west tunnel of Options 2a – 2c, respectively, will have very low impact on existing bridges and tunnel structures. These structures will nevertheless be subject to monitoring by way of baseline surveys and movement monitoring throughout the construction phase.

The specific advantage of largely following the Thames in this fashion minimises the key structures that require such monitoring. By interpolation it can also be assumed that, where the main tunnel routes pass under “dry land”, the potential impact on buildings will be negligible.

The introduction of the larger diameter east tunnels for Options 2a and 2b in particular is however another matter. As part of the current study a high level assessment was commissioned to determine the potential impact on the Northern Outfall Sewer, the EDF Cable Tunnels and the Network Rail tracks near Abbey Mills. The study conclusions were:

1. Predicted settlements and deformation of the EDF Cable Tunnels generated by the 13m diameter tunnel may be deemed unacceptable and the impact of the 10m diameter tunnel is significant.
2. The predicted settlements of the rail tracks are likely to be significant for the 13m and 10m diameter tunnels. This impact would be further exacerbated by the unavoidable necessity to traverse the tracks at an oblique angle.

3. The 7.2m diameter tunnel, of Option 1c, will generate lower ground movement and therefore the potential impact on the EDF Cable Tunnels and the rail tracks will be significantly less.
4. The Northern Outfall Sewer (NOS), which consists of five masonry barrels, is vulnerable to the potential impact of the 13m and 10m diameter tunnels, but calculated strains indicate that tunnel construction should not damage the NOS. By interpolation the potential impact of the 7.2m diameter is significantly less.

These findings seriously mitigate against adoption of the east tunnel of Options 2a and 2b.

5.3 Lining Design

For all options the main tunnel lining includes a primary segmental lining together with a secondary insitu reinforced concrete lining, which is intended to ensure water-tightness of the tunnel because of the perceived risk of contamination to the aquifer. However this secondary lining has a significant impact on cost and programme.

The alternative of a one pass lining system with enhanced joint detail was therefore investigated and found to be perfectly feasible as there are several examples of tunnel linings that have met the hydraulic pressure requirements. This aspect requires some further development at the next stage of the project, but is another potential improvement to cost and programme.

Generally the groundwater pressures will be higher than the internal hydraulic pressure of the tunnel. Therefore ingress is more likely to result. The only occasion when the situation is reversed is when the tunnel becomes full and surcharged. For Options 1a and 1c this will occur approximately three times per year and for approximately 24 hours (at the most) until the draindown regime reduces the level of stored flow and hence the internal pressure in the tunnel.

For these options therefore there is a very low risk of contamination of the aquifer. However for other options or partial options where tunnel surcharge occurs more frequently or for longer the risk of contamination will increase proportionally.

The decision on whether to adopt a one-pass lining system or not will be dependent upon a thorough risk assessment process (agreed with the Environment Agency) and some further development and tests on the gasket system. The avoidance of a secondary insitu lining would save significant cost and time for most options and is therefore a potential improvement that should be developed in the next phase of solution implementation

5.4 Geology and Site Investigation

Geological Specialists with specific and expert knowledge of the lithologies of the London Basin were commissioned to give their advice for the development of the current options, particularly in relation to shaft and tunnel construction. A thorough understanding of the geological strata and the engineering implications is absolutely paramount to the successful implementation of any of the options.

Their recommendations included:

1. Strategically planned and good quality ground investigations will be essential to obtain sufficient geotechnical data to understand the ground conditions along the tunnel route and thus be able to mitigate identified risks.
2. The Thanet Sand Formation, Lambeth Group and Quaternary sediments have varied lithologies and can have high permeabilities. A variety of complex Quaternary relict features are likely to exist, therefore an experienced Quaternary geologist should be involved during the ground investigations.

3. Close liaison between specialist clay mineralogists and tunnel boring machine (TBM) manufacturers could avoid problems arising from the presence of swelling clays. Tests should be carried out on borehole cores to establish parameters for the design of the TBM.
4. Potential oxygen depleting minerals need to be identified and monitored with appropriate health and safety measures put in place to protect the workforce.
5. The Lea Valley and Roding Valley both contain difficult ground conditions for tunnel construction. Since Chalk conditions between the two river valleys are more favourable, the direct tunnel route from Abbey Mills to Beckton is recommended over the Abbey Mills to Charlton route.
6. A 3D marine seismic survey of tunnel sections beneath the river combined with deep rotary cored boreholes are required to develop the conceptual ground model. Geophysics is also recommended to understand the ground conditions that will be encountered.
7. Testing should be undertaken to ascertain any issues relating to potential problems with reuse of excavated material including acidic conditions from pyrite and saline material.
8. A dedicated core store will be required at a location close to the scheme, to clean, log and store borehole cores.

As part of the current study three deep exploratory boreholes were constructed using a combination of cable tool percussive boring and rotary drilling. Extensive samples were taken and logged and extensive down-hole geophysical procedures were carried out. This preliminary investigation largely confirmed many of the assumptions made during previous desktop studies and the assessment of archive borehole logs.

5.5 PEER REVIEW

The tunnelling and shaft construction of the options has also 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 cost or programme beneficial.

6 RISKS AND 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 are the logistics of implementing the work within confined areas available for construction and a congested urban environment.

Of particular concern is the launching and recovery of the Tunnel Boring Machines from deep shafts for the large tunnels of the east tunnel of Options 2a – 2c. 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. However more confidence can be expressed for the construction of the 6m and 7.2m diameter tunnels of Options 1a – 1c as there is more experience of the launch and recovery of the TBMs of this size from deep shafts.

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 listed below:

1. All the main options require acquisition of land for 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.

2. Options 2a – 2c do not intercept the CSOs in the central section, therefore these would continue to discharge unimpeded to the River Thames. Although there would be a reduction in overall volume of discharge to 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.

3. The west tunnel of Options 2a – 2c is isolated from the main sewage treatment works, which are 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.

4. 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. However the geology for the route directly between Abbey Mills and Beckton is more predictable and therefore the risk is reduced.

5. Generally the geology for the tunnel routes following the River Thames is reasonably well understood and therefore more predictable. However there will be zones, particularly in the areas of the confluences with the lost rivers, 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, such as ground freezing, has been included in the scope and budget estimates.

6. Launching of the 10m and 13m diameter TBMs, for the east tunnel of Options 2a – 2c, from the shafts are likely to require the construction of significant underground chambers to facilitate TBM assembly. Excavation of these chambers would potentially involve large areas of unsupported ground during the construction sequence which would require extensive geotechnical works. Conversely the 6m and 7.2m diameter TBMs for Options 1a to 1c could be launched through portals in the shaft walls thus maintaining ground support during this operation. Therefore the launching of the 10m and 13m TBMs would incur significantly more risk.

7. Options 1a, 1b and 1c incorporate significantly more CSO interception works than the other options as they intercept all the category 1 and 2 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.

8. A particular issue is the proposed Victoria Embankment Project, which includes reduction of the highway from two lanes to single lanes in each direction and the creation of a promenade adjacent to the River Thames, due to be completed by 2010. This proposal would have a significant impact on the CSO interception works for this section, however there is the opportunity for collaborative working. The interceptions works could be brought forward to accommodate the Victoria Embankment Project in advance of the main tunnel works and then connected at a later date. Alternatively the interception works could be carried according to the current programmes in early 2017, some 7 years after completion of the Victoria Embankment Projects in the promenade section without impacting on traffic.

9. The CSO interception works as currently detailed for Brixton and Clapham Storm Relief Sewers would have a significant impact on traffic at Vauxhall. There are potential alternatives, based on locating the shaft in the foreshore adjacent to Vauxhall Bridge that could be implemented to reduce impact. These options would require development at the next stage of the project and in particular the relevant approvals from the Port of London Authority.

10. For Options 1a, 1b and 2c, together with their potential early phases, the transfer of Abbey Mills CSO flows to overflow Beckton requires the tunnel route and hence the main shaft at Charlton to be surcharged. Isolating penstock need to be closed during the event to prevent surcharge of the upstream CSOs and Charlton CSO. Significant flooding would result if these isolating penstocks failed open. The main shaft would also have to be extended above ground to prevent release of flow from the roof covers.

11. The tunnel route directly between Abbey Mills and Beckton will cross under the cable tunnels, currently under construction, near Abbey Mills. The predicted ground movements and deformation curvature are very significant for the 13m diameter tunnel and are therefore likely to be unacceptable. The potential impact from the 10m tunnels will be less, but still quite significant. The completed tunnels will house high voltage cables and a mini railway (for inspection purposes) and will not therefore be amenable to retrofit strengthening requirements. As there is no current direction for implementation of the Tideway scheme advance works cannot be incorporated in the current construction of the cable tunnels. It is likely therefore that the 7.2m tunnel would be the only practical option.

12. The tunnel route directly between Abbey Mills and Beckton will also cross under two railways. The crossing angle will unavoidably be oblique and therefore exacerbate the

potential impact of ground movements on the tracks. The likely impact of the 13m and 10m diameter tunnels will be significant, whereas the impact of the 7.2m will be within manageable limits.

7 CONCLUSIONS

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

This first phase would enable the transfer of Abbey Mills CSO flows to Beckton and prevent discharge to the River Lee. However this would result in a high frequency of untreated discharge at Beckton. This should be acceptable as an interim provision; however it would not be sustainable in the longer term. Therefore implementation of this first phase is an essential pre-cursor to completion to the full scheme the reduce the frequency of bypass

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

The programmed completion date of April 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 afterwards. In this manner approximately 6 months additional contingency could be invoked if necessary.

This potential time contingency should only be invoked as a means to recover from time lost due to construction difficulties and not as a means to delaying the commencement of the works.

Option 1a meets the quality objectives but does not entail a viable first phase for early implementation by 2012. The Abbey Mills to Charlton section of the tunnel will be subject to higher construction risk because of the 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.

Options 2a, 2b and 2c do not meet the DO objectives for sustainable fish populations and do not reduce the frequency of discharge. Pump-out from the west tunnel is operationally complex and incurs the risk of increased frequency or volume of discharge from downstream CSOs.

The east tunnel sections of Options 2a and 2b are not viable first phases for early implementation. The ground movements associated with construction of the 13m tunnel for Option 2a will have an unacceptable impact on the new cable tunnels and that of the 10m tunnel for Option 2b will have a significant impact. For all the other tunnel sections the potential impact on third party structures, such as tunnels, bridges and embankments the impact will be low or insignificant.

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 draindown and will, therefore be more likely to cause odour problems. The sequential draindown 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 and discharge chimneys for the exhaust, is proposed to minimise any potential odour.

It is proposed to transport the excavated material, or process arisings, from the main tunnel by river barges. Temporary jetties or extensions to existing jetties would be provided to accommodate this process. The scope and budget estimates for each option includes for disposal of the excavated material to landfill and therefore includes an allowance for Landfill Tax. In fact there are many potential uses for the material including engineering fill to prepare brownfield sites for redevelopment, capping of fill sites and pipeline backfill. In particular the opportunity to use the process arisings from the construction of the first phase of Option 1c as engineering fill on the Beckton Rectangle could be quite advantageous in terms of cost and time. Many of these options for use of the process arisings may save cost and improve the environmental credibility of the scheme. However the viability of these options is dependent on the proposed programme since potential sites to accommodate materials need to be available at the appropriate time.

For all options the main tunnel lining includes a primary segmental lining together with a secondary insitu reinforced concrete lining, which is intended to ensure water-tightness of the tunnel because of the perceived risk of contamination to the aquifer. However this secondary lining has a significant impact on cost and programme. The alternative of a one pass lining system with enhanced joint detail was therefore investigated and found to be perfectly feasible as there are several examples of tunnel linings that have met the hydraulic pressure requirements. This aspect requires some further development at the next stage of the project, but is another potential improvement to cost and programme.

The tunnelling and shaft construction of the options has also 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 cost or programme beneficial.

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