Site selection
background technical paper

Phase two consultation
Thames Tunnel

Site selection background technical paper

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List of abbreviations

AOD above Ordnance Datum
ATD above tunnel datum
CSO combined sewer overflow
EPB earth pressure balance
PS pumping station
SR storm relief
STW sewage treatment works
TBM tunnel boring machine
1 Background

1.1 Purpose

1.1.1 This Site selection background technical paper, Summer 2011 issue, accompanies the Site selection methodology paper and the Phase two scheme development report and is an update to the Spring 2010 issue that accompanied the Project Overview at phase one consultation. The aim of this Site selection background technical paper, Spring 2011, is to provide information for the site selection team about the background and the engineering requirements of the Thames Tunnel project.

1.1.2 This update to the Site selection background technical paper includes the engineering requirements that have a bearing on the site selection process, incorporating the developments in the engineering design that occurred during the course of site selection, leading up to the phase two public consultation on the preferred sites and tunnel route.

1.2 History

1.2.1 London’s sewer system was designed in the 1800s to handle wastewater and runoff rainwater through a combined collecting system. Combined sewer overflows (CSOs) were incorporated into the sewer system as relief structures to prevent flooding caused by sewer overloading, especially during periods of heavy rainfall.

1.2.2 The capacities originally allowed for in the interceptor and combined sewer systems designed by Sir Joseph Bazalgette in the 1850s (and subsequently extended) have now been substantially exceeded. Despite improvements over the years, there is little spare capacity in the sewerage network as a whole. This is due to factors such as the increase in population and water usage, and increased hardstanding areas (which reduces the capability of the land to absorb rainwater, which instead enters the sewerage network more rapidly). It now only takes as little as a few millimetres of rainfall to cause some CSOs to discharge combined sewage into the River Thames.

1.2.3 Currently, overflows from the sewers to the Thames Tideway (being the tidal reaches of the River Thames) occur more than 50 times per year at the most frequently overflowing CSOs. An estimated total of some 39 million cubic metres of combined sewage (which is untreated sewage combined with rainwater) enter the river from the Beckton and Crossness sewerage catchments in a typical year. Figure 1.1 illustrates Mogden, Beckton and Crossness sewerage catchments.
1.2.4 There is a need to reduce these overflow incidents in order to comply with legal requirements and to abide by the UK Government’s request for Thames Water to implement a solution. A number of potential options and solutions for meeting this obligation have been examined through the work of the Thames Tideway Strategic Study (TTSS). The Thames Tunnel project, in conjunction with the Lee Tunnel and upgrades to London’s sewage treatment works, has been determined by independent studies and confirmed by Thames Water to be the best technological solution and cost-effective means to deal with the discharges and to meet the regulatory requirements.

1.3 The combined sewer overflows

1.3.1 The Environment Agency1 evaluated 57 CSOs and has identified 36 of these as unsatisfactory, of which 34 require control through the Thames Tunnel project. Figure 1.2 illustrates graphically where the 34 CSOs to be controlled by the Thames Tunnel project are located.

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1 The Environment Agency (EA) is an executive non-departmental public body responsible to the Secretary of State for Environment, Food and Rural Affairs (Defra) in England. The EA plays a central role in delivering the environmental priorities of central Government through its functions and roles. More specifically, the Environment Agency is responsible for determining the acceptability of discharges associated with the treatment of wastewater (including combined sewage).
1.4 The proposed solution

1.4.1 The Thames Tunnel project would comprise a main tunnel, running from west to east London, integrated with the existing sewerage system via connection tunnels, to control 34 of the most polluting CSOs. These tunnels would store and transfer the intercepted flows to Beckton Sewage Treatment Works.

1.4.2 The project consists of two main elements:

a. Works to design, construct and maintain the main tunnel, which would provide the majority of the storage capacity and enable transfer of combined sewage to Beckton STW in east London.

b. Works to control combined sewage overflows from the worst polluting CSOs and transfer them into the main tunnel. This would include connection tunnels to link intercepted CSOs to the main tunnel.

1.4.3 Other elements would comprise:

a. local modifications to existing structures and pumping stations in the sewerage systems

b. works to drain down the system at the Beckton STW end.

1.4.4 The Thames Tunnel project is therefore a major linear infrastructure scheme that would extend across 14 local authorities.

1.5 Need

1.5.1 The objective of the European Union (EU) Urban Waste Water Treatment Directive (UWWTD) is to protect the environment from the adverse effects of insufficiently treated wastewater discharges. Wastewater collecting systems in London, according to the European Commission, the Government, the Environment Agency and Thames Water, spill untreated wastewaters from CSOs too frequently and in excessive quantities, and are consequently in breach of the UWWTD. The Directive and related UK legislation (the Urban Waste Water Treatment Regulations 1994 (UWWTR) (SI 1994/2841)) transpose the UWWTD into UK law. Both EU
1 Background

and UK regulations accept that wastewater collection systems and treatment works may spill wastewater in certain situations, such as a result of unusually heavy rainfall, but the Commission considers that spills in the case of London are excessive and go beyond what the legislation allows for.

1.5.2 The European Commission has given formal notice that it considers the UK to be in breach of the UWWTD. The Commission has commenced legal proceedings against the UK for failure to comply with the UWWTD in respect of the River Thames Tideway.

1.5.3 The UK Government has made a number of announcements in relation to the project and what is expected of Thames Water. On 22 March 2007, the Minister for Climate Change and the Environment, Ian Pearson, announced the Government’s decision on the full-length tunnel project in a written answer (Hansard Col 53WS), as follows:

“These overflows are having an adverse effect on the environmental quality of the Thames. It has been found that the frequent overflows (on average once a week) and the large quantities of untreated discharges are causing:

adverse environmental impacts on fish species;

unacceptable aesthetic issues; and

elevated health risks for recreational users of the Thames.

… I have carefully considered the reports Thames Water submitted to me at the end of 2006 and met with stakeholders who were involved in this work to hear their views. A Regulatory Impact Assessment has been completed and is available on the Defra website. Today I am announcing the Government decision for an Option 1 type solution. … This approach is needed to provide a River Thames fit for London in the 21st century and to meet the statutory requirements of the (UWWTR 1994)....Thames Water, the Environment Agency, the Water Services Regulation Authority and others will be taking this forward for planning and funding applications. Government will be closely following this detailed work as it develops.”

1.5.4 On 17 April 2007, Ian Pearson wrote to the Chief Executive Officer of Thames Water in the following terms:

“I am writing to request that Thames Water makes provision for the design, construction, and maintenance of a scheme for the collecting systems connected to Beckton and Crossness sewage treatment works which:

• involves a full-length storage tunnel with additional secondary treatment at Beckton sewage treatment works;

• meets the requirements of the 1994 Regulations, including for sewerage undertakers to ensure that the design, construction and maintenance of collecting systems is undertaken in accordance with best technical knowledge not entailing excessive cost (BTKNEEC);

• complies with discharge consent conditions as will be set by the Environment Agency, in exercise of its duty under regulation 6(2) of...
1 Background

the 1994 Regulations, to secure the limitation of pollution of the tidal Thames and River Lee due to storm water overflows;

- limits overflow discharges at Abbey Mills Pumping Station as soon as possible.”

1.5.5 On 7 September 2010, the present Secretary of State, Caroline Spelman, issued a statement which confirmed the need for the project. She stated:

“… a Thames Tunnel continues to offer (by far) the lowest cost solution to the problem and I believe Thames Water should continue to press forward with this project working with Ofwat, the Environment Agency and Defra on the regulatory, commercial and planning processes.”

1.5.6 The Planning Act 2008 was introduced in response to widespread acceptance that large infrastructure projects in England and Wales were taking too long to work through the planning system. The Act introduced national policy statements to set out clearly what the policy was in respect of various types of infrastructure.

1.5.7 The draft National Policy Statement for Waste Water (published on 16 November 2010) endorses the need for the Thames Tunnel project and states at Section 4:

“These improvement works are required to enable us to continue to meet our obligations under the Urban Waste Water Treatment Directive. The urgency of the works is increased by the infraction proceedings being pursued against the UK by the European Commission for an alleged breach of the Directive.” (Paragraph 4.1.4)

“It is essential to reduce the likelihood of such incidents, which also have a reputational impact on the UK, as they take place in the capital city’s river. The … impacts impose an economic cost on the capital, country and society. These costs include direct financial costs such as the costs of measures to mitigate against low oxygen, fish re-stocking, costs on the health service and the wider economy due to people falling ill and costs of cleaning up debris.” (Paragraph 4.2.4)

1.5.8 A detailed Needs Report on the need for the Thames Tunnel was published in summer 2010 (see website). A summary, updated version, Why does London need the Thames Tunnel?, was published in July 2011 and is also available at the Thames Tunnel consultation website. The documents provide more detail on the requirement for the Thames Tunnel project, explaining how, even after the provision of the Lee Tunnel and the commissioning of the Mogden, Beckton, Crossness, Riverside and Long Reach STW improvements, the UK will still fail to comply with the requirements of the relevant legislation. Only the completion of the project will provide the infrastructure necessary for compliance with the UWWTD, by limiting the frequency and volume of combined sewer discharges and thereby reducing pollution due to stormwater overflows, to meet dissolved oxygen (DO) standards in the river set by the EA for the River Thames.
1.6 **Stages of the Thames Tunnel project**

1.6.1 The project is subject to many external influences, notably the outcome of public consultations and the planning process, but also government direction, regulatory approval and funding will dictate the pace of any implementation.

1.6.2 The main development and implementation steps required for the project to be delivered are all linked together and include:

a. design  
b. planning and consenting  
c. communication and consultation  
d. field investigations  
e. land acquisition  
f. procurement  
g. enabling works  
h. construction  
i. commissioning  
j. operation.

1.7 **Structure of this document**

1.7.1 This document:

a. describes the scope of the Thames Tunnel project in more detail (Section 2)  
b. describes the components and site requirements associated with the CSOs and local modifications to the sewerage network (Section 3)  
c. describes the components and site requirements associated with the main tunnel (Section 4).
2 Scope of the project

2.1 Concept

2.1.1 The general objective of the Thames Tunnel project is to comply with the UWWTD by controlling unacceptable CSOs as designated by the EA. The project would:

a. control and capture CSO discharges
b. store the CSO discharges
c. transfer the CSO discharges for treatment.

2.2 CSO discharge control

2.2.1 During and following storm events, when the sewers are unable to handle extra flow and would otherwise overflow to the river, interception works would divert CSO discharge flows into the tunnel system for storage before transfer for treatment.

2.2.2 CSO flows would be diverted by building a series of structures, known as CSO interception works, to divert the flows from existing sewers into the tunnel system.

2.2.3 Design development has shown that not all of the 34 CSOs would require their own individual CSO interception works in order for them to be adequately controlled. For some CSOs, it should be possible to use existing sewers and pumping station operation modifications to control their overflows at one of the other CSO interception works locations. This has the advantage of reducing the number of CSO sites required. It is envisaged that there would be:

a. some CSOs that would be directly controlled by being intercepted, which would only deal with the flows from one CSO
b. some CSOs that would be directly controlled by being intercepted, which would also need to deal with the flows from CSOs that would not be directly controlled
c. some CSOs where two connections would be needed: one to intercept the flows from the CSO and one to divert some of the flows from another existing sewer. The flows from some other CSOs would be controlled as a result of these double connections so that no modifications would be required at them at all
d. some CSOs that would not be directly controlled through interception, but would be indirectly controlled through modifications to change the operation of the existing sewerage system, including:
   i. adjustments to existing pumping stations
   ii. local in-sewer modifications that allow flows to be passed forward through the existing sewer system to the treatment works, or to be passed to other CSOs that would be intercepted.
2.2.4 Further studies are required to refine the method of flow control for each CSO, but current findings are that 16 CSOs can be indirectly controlled, reducing the number of CSOs needing to be intercepted from 34 to 18.

2.2.5 The proposed method of flow control of the 34 CSOs to be dealt with is listed in Table 2.1 and described further in sections 3.1 and 3.2.

<table>
<thead>
<tr>
<th>CSO ref</th>
<th>Combined sewer overflow</th>
<th>Method of overflow control</th>
</tr>
</thead>
<tbody>
<tr>
<td>CS01X</td>
<td>Acton Storm Relief</td>
<td>Interception</td>
</tr>
<tr>
<td>CS02X</td>
<td>Stamford Brook Storm Relief</td>
<td>Control measures at other CSOs indirectly controls this CSO</td>
</tr>
<tr>
<td>CS03X</td>
<td>North West Storm Relief</td>
<td>Interception and pumping station operation changes at Hammersmith Pumping Station indirectly control this CSO</td>
</tr>
<tr>
<td>CS04X</td>
<td>Hammersmith Pumping Station</td>
<td>Interception and pumping station operation changes</td>
</tr>
<tr>
<td>CS05X</td>
<td>West Putney Storm Relief</td>
<td>Interception</td>
</tr>
<tr>
<td>CS06X</td>
<td>Putney Bridge</td>
<td>Interception</td>
</tr>
<tr>
<td>CS07A</td>
<td>Frogmore Storm Relief – Bell Lane Creek</td>
<td>Interception</td>
</tr>
<tr>
<td>CS07B</td>
<td>Frogmore Storm Relief – Buckhold Rd</td>
<td></td>
</tr>
<tr>
<td>CS08A</td>
<td>Jews Row Wandle Valley Storm Relief *</td>
<td>Modifications already in place so CSO is indirectly controlled</td>
</tr>
<tr>
<td>CS08B</td>
<td>Jews Row Falconbrook Storm Relief*</td>
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</tr>
<tr>
<td>CS09X</td>
<td>Falconbrook Pumping Station</td>
<td>Interception</td>
</tr>
<tr>
<td>CS10X</td>
<td>Lots Road Pumping Station</td>
<td>Interception</td>
</tr>
<tr>
<td>CS11X</td>
<td>Church Street</td>
<td>Controlled indirectly by sewer connection relief works at other CSOs**</td>
</tr>
<tr>
<td>CS12X</td>
<td>Queen Street</td>
<td>Controlled indirectly by sewer connection relief works at other CSOs**</td>
</tr>
<tr>
<td>CS13A</td>
<td>Smith Street – Main Line</td>
<td>Controlled indirectly by sewer connection relief works at other CSOs**</td>
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<tr>
<td>CS13B</td>
<td>Smith Street – Storm Relief</td>
<td></td>
</tr>
<tr>
<td>CS14X</td>
<td>Ranelagh</td>
<td>Interception and additional sewer connection relief**</td>
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## Scope of the project

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<tr>
<th>CSO ref</th>
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<th>Method of overflow control</th>
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<tr>
<td>CS15X</td>
<td>Western Pumping Station</td>
<td>Controlled indirectly by sewer connection relief works at other CSOs**</td>
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<tr>
<td>CS16X</td>
<td>Heathwall Pumping Station</td>
<td>Interception</td>
</tr>
<tr>
<td>CS17X</td>
<td>South West Storm Relief</td>
<td>Interception</td>
</tr>
<tr>
<td>CS18X</td>
<td>Kings Scholars Pond</td>
<td>Controlled indirectly by sewer connection relief works at other CSOs*</td>
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<tr>
<td>CS19X</td>
<td>Clapham Storm Relief</td>
<td>Interception</td>
</tr>
<tr>
<td>CS20X</td>
<td>Brixton Storm Relief</td>
<td>Interception</td>
</tr>
<tr>
<td>CS21X</td>
<td>Grosvenor Ditch</td>
<td>Controlled indirectly by sewer connection relief works at other CSOs**</td>
</tr>
<tr>
<td>CS22X</td>
<td>Regent Street</td>
<td>Interception and additional sewer connection relief**</td>
</tr>
<tr>
<td>CS23X</td>
<td>Northumberland Street</td>
<td>Controlled indirectly by sewer connection relief works at other CSOs**</td>
</tr>
<tr>
<td>CS24X</td>
<td>Savoy Street</td>
<td>Controlled indirectly by sewer connection relief works at other CSOs**</td>
</tr>
<tr>
<td>CS25X</td>
<td>Norfolk Street</td>
<td>Controlled indirectly by sewer connection relief works at other CSOs**</td>
</tr>
<tr>
<td>CS26X</td>
<td>Essex Street</td>
<td>Controlled indirectly by sewer connection relief works at other CSOs**</td>
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<tr>
<td>CS27X</td>
<td>Fleet Main</td>
<td>Interception and additional sewer connection relief**</td>
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<tr>
<td>CS28X</td>
<td>Shad Thames Pumping Station*</td>
<td>Pumping station modifications</td>
</tr>
<tr>
<td>CS29X</td>
<td>North East Storm Relief</td>
<td>Interception</td>
</tr>
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<td>CS30X</td>
<td>Holloway Storm Relief*</td>
<td>Local modifications</td>
</tr>
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<td>CS31X</td>
<td>Earl Pumping Station</td>
<td>Interception</td>
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<td>CS32X</td>
<td>Deptford Storm Relief</td>
<td>Interception</td>
</tr>
<tr>
<td>CS33X</td>
<td>Greenwich Pumping Station</td>
<td>Interception and pumping station operation changes</td>
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2 Scope of the project

<table>
<thead>
<tr>
<th>CSO ref</th>
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<th>Method of overflow control</th>
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<tbody>
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<td>CS34X</td>
<td>Charlton Storm Relief</td>
<td>Controlled by operation changes at Greenwich Pumping Station and improvements at Crossness STW</td>
</tr>
</tbody>
</table>

* These CSOs were planned to be controlled via interception at phase one consultation stage

** The additional sewer connection relief would be connections into the northern Low Level Sewer No.1 at Ranelagh, Regent Street and Fleet Main CSOs.

2.2.6 The system design would be such that interception of CSO discharges and the storage and transfer of the flow in the tunnel system would be controlled by mechanical equipment, such as hydraulic gates, valves or penstocks, to control or direct the flows.

2.2.7 There would be no requirements for on-site operational personnel to actively operate the interception and storage aspects of the system. Control of the system would be mainly through the measurement of tunnel water levels, with overview of the system at a central control centre. Periodic access for maintenance would, however, be necessary.

2.3 Storage, transfer and treatment of CSO discharges

2.3.1 The CSO discharges passing into the tunnel system (ie, the main tunnel and the network of connection tunnels that link the CSO interception structures with the main tunnel) would mainly flow in by gravity. However, some interception works would be located downstream of existing pumping stations and therefore pumping of the flow would continue. The CSO discharges would flow by gravity along the tunnel system to a pumping station in Beckton STW, known as the Tideway Pumping Station. The flow would be stored in the tunnel system until it can be transferred to Beckton STW for treatment. The Tideway Pumping Station would transfer the flows for full treatment when sewage treatment capacity is available.

2.3.2 The Tideway Pumping Station would, at times, transfer some flow from the tunnel to the overflow shaft built as part of the Lee Tunnel project. This transfer of bypass pumping is required to achieve the overall level of control targeted for the River Thames CSOs, and for discharge control for the Abbey Mills CSO.

2.3.3 Additional treatment capacity is being provided at Beckton STW as part of a separate project to extend and upgrade Beckton STW. This would provide sufficient capacity to treat the stored flows from the Lee Tunnel and Thames Tunnel projects.

2.3.4 For transfer of flows to Beckton STW for treatment, three main tunnel routes were considered: The River Thames Route, the Rotherhithe route and the Abbey Mills route. The three routes, which are described below and shown in Figure 2.1, were those presented at phase one consultation.
2 Scope of the project

The River Thames route

2.3.5 The alignment of this route largely follows the river from west London to Beckton STW but cuts across the Greenwich Peninsula, where there are no CSOs to be intercepted along the river. This route, which has a length of approximately 32km and a depth of 40m in west London and 75m in east London, is derived from the 2006 Option Development Report\(^2\) (Option 1c).

The Rotherhithe route

2.3.6 The alignment of this route is similar to the River Thames alignment but it also cuts across the Rotherhithe Peninsula, reducing the length of the main tunnel by approximately 1.8km but requiring longer connection tunnels from some CSOs. This route also has a depth of 40m in west London and 75m in east London.

The Abbey Mills route

2.3.7 The alignment of this route follows the River Thames route between west London and Rotherhithe, but then moves away from the River Thames north-eastwards to terminate at Abbey Mills Pumping Station, reducing the length of the main tunnel by approximately 9km. This route also has a depth of 40m in west London, but 65m in east London. The length of the connection tunnels increases east of where the tunnel diverges from the river towards Abbey Mills. The flows from the Thames Tunnel main tunnel would be transferred to Beckton STW via the Lee Tunnel. With this route, Charlton SR CSO would not be connected to the main tunnel but indirectly controlled by system modifications including improvements to Crossness STW.

2.3.8 The Abbey Mills route was presented as the preferred route at phase one consultation. The Report on Phase One Consultation reported on the feedback from phase one consultation and concluded that the Abbey Mills route remains the preferred route. Consequently, the main tunnel referred to in the remainder of this Site selection background technical paper is the main tunnel associated with the Abbey Mills route, and the Rotherhithe and River Thames routes are not considered further.

---

2 Scope of the project

Figure 2.1 Routes considered

Key
- Route common to all three options
- Connection Tunnels (all routes)
- Abbey Mills Route (preferred)
- River Thames Route
- Rotherhithe Route
- Rotherhithe Route Connection Tunnels

Legend
- Orange
- Light orange
- Light orange with black outline
- Dark orange
- Dark orange with black outline
- Black dashed line
- Black dashed line with dark orange outline
- Dark orange with black outline dashed line

Sites
- Ealing
- Hammersmith & Fulham
- Kensington & Chelsea
- Hounslow
- Richmond-upon-Thames
- Wandsworth
- City of Westminster
- City of London
- Tower Hamlets
- Newham
- Greenwich
- Lee Tunnel
- Beckton Sewage Treatment Works
2.4 Type of sites required

2.4.1 Two principal types of sites would be required to construct and operate the project:
   a. CSO sites (CSO interception works including the connection tunnels)
   b. Main tunnel sites.

2.4.2 The selection of CSO sites and main tunnel sites will be carried out in accordance with the Site selection methodology paper.

2.4.3 Other types of sites would also be required where the location of the site is determined by the permanent works to be undertaken. These include:
   a. extension of the pumping capacity by the addition of two pumps in the Tideway Pumping Station and works to transfer the flows from the Tideway Pumping Station to the inlet works at Beckton STW
   b. installation of additional mechanical and electrical equipment at the inlet works of Beckton STW
   c. a siphon tunnel in Beckton STW to transfer tunnel overflows to the Lee Tunnel overflow shaft.
   d. local in-sewer modifications which would be accessed, where possible, via existing sewer manholes
   e. pumping station modification of the operating strategies would occur at existing pumping stations.

2.4.4 It is likely that there would also be other areas which contractors would use that are required for temporary construction activities which are not part of the project's permanent works and operations. These areas could include:
   a. a concrete segment factory for the primary tunnel lining
   b. logistics hubs/assembly areas for the co-ordination of materials and associated transport
   c. vehicle marshalling areas for security and to limit traffic queuing
   d. in-river areas for temporary mooring of barges, and trans-shipment areas to transfer materials between large and small barges and transfer materials between river and land
   e. areas above the line of the tunnels for ground treatment
   f. other similar construction facilities.
3 Combined sewer overflows

3.1 Components – CSO interception

3.1.1 For the CSOs where direct control by interception works would be required, the objectives for the interception of flows are to be able to:
   a. redirect and control flows from the combined sewer
   b. transfer flows from the combined sewer down into the main tunnel
   c. continue to use the existing river outfall, or construct new outfalls to use when the tunnel is full, to direct residual flow to the River Thames.

3.1.2 Typical components of CSO interception works are shown diagrammatically in Figure 3.1 and comprise:
   a. an interception chamber
   b. valve chambers
   c. ventilation structures
   d. a connection culvert
   e. a drop shaft containing a vortex drop structure
   f. a connection tunnel.

Figure 3.1 Isometric view of CSO interception arrangements
3.1.3 There are five basic arrangements for connections between the main tunnel and existing combined sewers. A CSO could be connected to the main tunnel via:

a. a connection tunnel that is connected to a shaft on the main tunnel (Type A)

b. a connection tunnel that is connected to the main tunnel (Type B)

c. a connection tunnel that is connected to another CSO drop shaft (Type C)

d. a drop shaft that lies directly adjacent to the main tunnel so that a connection tunnel is not required (Type D)

e. a shaft on the main tunnel so that a connection tunnel is not required (Type E) and this arrangement has two possibilities:
   i. the shaft is a main tunnel shaft
   ii. the shaft is a CSO drop shaft.

**Interception chamber**

3.1.4 The interception chamber intercepts flows en route to the outfall to transfer them to the main tunnel. When the tunnel system is full, the chamber would revert to existing conditions and allow overflow to the river.

3.1.5 Provision would be made at interception chambers to provide safe working within the downstream system. Safe working would be aided by locking penstocks shut during periods of access to the tunnel system.

3.1.6 To protect the tunnel system from inflow as the result of high water levels in the River Thames, backflow protection would be provided by new one-way flap valves. Secondary protection would be provided by existing tide gates and, if necessary, by closure of the control penstocks.

3.1.7 Flow control equipment and penstocks would be incorporated into the interception chamber where practicable, but may need to be housed in separate valve chambers. The electrical or hydraulic components of the flow control equipment would be housed in an industrial kiosk/cabinet.

**Ventilation structures**

3.1.8 When the system fills with CSO discharges, the air in the tunnels would be displaced, and when the flow is removed from the tunnels, air would need to return. When the tunnels are empty, the design also includes a means of refreshing the air within the tunnels. Therefore, the interaction of combined sewage inflow and management of air requirements are considered and addressed.

3.1.9 The air management system would involve a combination of air extraction, air intake structures, and buildings to house air treatment equipment. The size and configuration of the structures would depend primarily on how air moves through the system and the amount of air to be moved.

3.1.10 At most sites, passive air management facilities would be provided. There would be some active mechanical ventilation plants provided as part of the
Thames Tunnel project. All the active mechanical ventilation plants along the whole tunnel system would work in conjunction to provide ventilation for the entire tunnel system to avoid nuisance odours from occurring.

3.1.11 Air management facilities and air releases would be monitored, and most aspects of the air management system would be designed to operate automatically. Therefore, no on-site personnel would be required to operate the air management facilities, but access to the facilities would be needed for maintenance.

Connection culvert

3.1.12 The connection culvert takes flows from the interception chamber into a drop shaft. The connection culvert can have several sections, depending on the location of valves and penstocks. The connection culvert would contain depth measurement access points to enable flow control and closure of penstocks when required.

Drop shaft

3.1.13 The drop shaft transfers flows vertically from the connection culvert to the deeper connection tunnel or main tunnel. The transfer of flow from the connection culvert down to the much deeper tunnel would be through a vortex drop structure inside the drop shaft. The vortex drop structure allows the dissipation of the energy created through the large drop height and de-aeration of the flow at the bottom of the shaft.

3.1.14 It is not possible to connect interception chambers directly into the main tunnel or connection tunnel because the tunnel is much deeper. Therefore, deep drop shafts would be introduced to give an acceptable gradient for the connection tunnels, and an operationally safe means of hydraulic transfer of flows from the relatively shallow surface facilities to depth.

3.1.15 It is envisaged that drop shaft diameters would generally range from 6m to 15m internal diameter, with a few ranging between 15m and 25m. The drop shaft size would be dependent on:

a. the arrangement for dropping the flow and associated de-aeration method (vertical or horizontal)

b. the rate of flow down the drop shaft, and hence the vortex structure dimensions

c. the ground conditions affecting the method of construction

d. the size of the associated connection tunnel

e. whether the drop shaft is constructed along the line of the main tunnel or a connection tunnel, or offset to these tunnels.

Connection tunnel

3.1.16 Connection tunnels take flows either between two drop shafts or from one drop shaft to the main tunnel.
3.1.17 Connection tunnel tunnels can join the main tunnel system either at shafts on the main tunnel or directly into the main tunnel. Connection tunnel to main tunnel junctions are possible in competent ground conditions, such as London Clay. However, in deep water-bearing ground such as Chalk, it is preferable to use connection tunnel to main tunnel shaft junctions. The construction of a connection directly into the main tunnel is more difficult to build and the connection works at a shaft would not interfere with the progress of the main tunnel construction.

3.1.18 Connection tunnels between CSO drop shafts combine flows from two or more CSOs before a connection tunnel connects to the main tunnel. The depth of the connection tunnels between drop shafts would be determined according to ground conditions and whether or not there is a need to avoid underground obstructions or sensitive infrastructure. The depth of the ultimate connection tunnel that connects to the main tunnel is also dependent upon the depth of the main tunnel. The circumstances in which such a tunnel might be adopted include:

a. where two interception chambers are close together, such that the length of the tunnels connecting the CSOs and then connecting to the main tunnel at one point would be less than the length of two separate tunnels directly connecting the CSOs with the main tunnel

b. where it would be considered prudent to reduce the number of connections into the main tunnel; for example, because of difficult ground conditions, proximity to sensitive infrastructure or underground obstructions.

3.2 Components – local modifications

3.2.1 Of the CSOs that are currently planned to be indirectly controlled with no direct interception, some of them incorporate local modifications but others require none. It is anticipated that where modifications are required, they would differ for each CSO as follows:

a. Stamford Brook Storm Relief CS02X – none required, as control measures at other CSOs indirectly control the Stamford Brook Storm Relief CSO flows.

b. North West Storm Relief CS03X – none required, as modifications to the operation of Hammersmith Pumping Station and the interception of the Hammersmith Pumping Station CSO would be sufficient.

c. Jews Row (Wandle Valley Storm Relief CS08A) and Jews Row (Falconbrook Storm Relief CS08B) – none required, as modifications previously undertaken are sufficient.

d. Church Street CS11X – none required, as three new connections made between the northern Low Level Sewer No.1 and the main tunnel at Ranelagh, Regent Street and Fleet Main CSOs would be sufficient to control a number of other CSOs. The connection at Ranelagh CSO contributes the most to the control of the Church Street CSO flows.
e. Queen Street CS12X – none required, as three new connections made between the northern Low Level Sewer No.1 and the main tunnel at Ranelagh, Regent Street and Fleet Main CSOs would be sufficient to control a number of other CSOs. The connection at Ranelagh CSO contributes the most to the control of the Queen Street CSO flows.

f. Smith Street (Main Line CS13A and Storm Relief CS13B) – none required, as three new connections made between the northern Low Level Sewer No.1 and the main tunnel at Ranelagh, Regent Street and Fleet Main CSOs would be sufficient to control a number of other CSOs. The connection at Ranelagh CSO contributes the most to the control of the Smith Street CSO flows.

g. Western Pumping Station CS15X – the control and operation of the pumps would be altered, and the new connection made between the northern Low Level Sewer No.1 and the main tunnel at Ranelagh CSO would be sufficient to control the Western Pumping Station CSO flows.

h. Kings Scholars Pond CS18X – none required, as three new connections made between the northern Low Level Sewer No.1 and the main tunnel at Ranelagh, Regent Street and Fleet Main CSOs would be sufficient to control a number of other CSOs. The connections at Ranelagh and Regent Street CSOs contribute the most to the control of the Kings Scholars Pond CSO flows.

i. Grosvenor Ditch CS21X – none required, as three new connections made between the northern Low Level Sewer No.1 and the main tunnel at Ranelagh, Regent Street and Fleet Main CSOs would be sufficient to control a number of other CSOs. The connections at Ranelagh and Regent Street CSOs contribute the most to the control of the Grosvenor Ditch CSO flows.

j. Northumberland Street CS23X – none required, as the adjacent interception of the Regent Street CSO and three new connections made between the northern Low Level Sewer No.1 and the main tunnel at Ranelagh, Regent Street and Fleet Main CSOs would be sufficient to control a number of other CSOs. The connection at Regent Street CSO contributes the most to the control of the Northumberland Street CSO flows.

k. Savoy Street CS24X – no interception required, as three new connections made between the northern Low Level Sewer No.1 and the main tunnel at Ranelagh, Regent Street and Fleet Main CSOs would be sufficient to control a number of other CSOs. The connections at Regent Street and Fleet Main CSOs contribute the most to the control of the Savoy Street CSO flows.

l. Norfolk Street CS25X – none required, as three new connections made between the northern Low Level Sewer No.1 and the main tunnel at Ranelagh, Regent Street and Fleet Main CSOs would be sufficient to control a number of other CSOs. The connections at Regent Street and Fleet Main CSOs contribute the most to the control of the Norfolk Street CSO flows.
m. Essex Street CS26X – none required, as three new connections made between the northern Low Level Sewer No.1 and the main tunnel at Ranelagh, Regent Street and Fleet Main CSOs would be sufficient to control a number of other CSOs. The connections at Regent Street and Fleet Main CSOs contribute the most to the control of the Essex Street CSO flows.

n. Shad Thames Pumping Station CS28X – modifications at Shad Thames Pumping Station are proposed to improve the use of the existing sewerage network. The works include modifications to the pumps and internal pipework, demolition of a building and construction of a new building to house electrical equipment, and modifications to the existing sewers outside the pumping station.

o. Holloway Storm Relief CS30X – a new penstock and valve chamber are proposed to be provided and existing weir enhanced in Bekesbourne Street.

p. Charlton Storm Relief CS34X – none required, as modifications being carried out in a separate project at Crossness STW (as part of the Sewage Works Upgrades) and modified operation of Greenwich Pumping Station would be sufficient.

### 3.3 CSO Sites – construction phase

#### Purpose

3.3.1 The CSO sites are required to construct the CSO interception system of structures, described in Section 3.1.2.

3.3.2 Ideally, the CSO interception sites would include all the facilities from the interception chamber to the drop shaft within the same site. However, where suitable sites are not on the line of the existing sewers, it would not be possible for the interception chamber and drop shaft to be located together, and the interception chamber would need to be constructed in a separate but smaller site.

#### Timing

3.3.3 The period that CSO sites would be required for construction would differ widely between CSOs because the construction activity would vary, depending on:

a. the diameter and length of the associated connection tunnels
b. the diameter of the drop shaft
c. the method of connection tunnel and drop shaft construction
d. the space available for the construction activities
e. the constraints to site access
f. whether the drop shaft is used as a drive shaft or reception shaft for the connection tunnel
3.3.4 It is anticipated that the construction at CSO sites would typically take two and a half to three and a half years, but may range from two to five years (excluding advance works such as utility connections and utility diversions).

**Location and search area**

3.3.5 The location of CSO sites is governed by the location of the existing combined sewers, because the interception chambers have to be built on the existing sewers. Therefore, the search area for the CSO sites was localised around the vicinity of the existing CSO.

3.3.6 The number of interception chambers can be minimised if they are located on the last section of sewer, where they converge before the overflow into the river. If the combined sewers were intercepted prior to convergence, several interception chambers would be required, as one interception chamber would be needed for each branch.

3.3.7 Consideration was also given to the feasibility of in-river CSO interception and drop shaft sites located on the foreshore, adjacent to the point of the existing overflow.

3.3.8 The search area for CSO sites varied with each CSO, as it depended on the sewer network upstream and downstream of the current overflow structure and the river outfall/outlet location. Therefore, each search area was defined once the local network characteristics had been determined.

**Construction method and site activities**

3.3.9 Interception chambers would be constructed via open excavations.

3.3.10 Connection culverts would be constructed using either cut-and-cover (open trench) or tunnelling techniques.

3.3.11 Drop shafts would be lined with concrete and may be constructed in different ways, such as:
   a. a diaphragm wall (concrete walls constructed in the ground before the ground in the centre is excavated)
   b. a caisson (precast concrete walls constructed at surface level and, as excavation progresses, they sink by combination of self-weight, ballast placed on top, or by hydraulic jacks)
   c. underpinning (precast concrete walls constructed at the bottom of the shaft as excavation progresses)
   d. sprayed concrete linings
   e. other methods, such as secant piled support.

3.3.12 The construction method chosen for each shaft would depend on ground conditions, shaft diameter, shaft depth and space constraints. Diaphragm
wall construction typically requires more space than caisson or underpinning construction techniques.

3.3.13 Typically, diaphragm walls are necessary for deep shafts with high groundwater pressures; caissons are used in water-bearing ground; and underpinning and sprayed concrete are used in cohesive non or low water-bearing ground. A combination of these and other techniques may be appropriate to construct a shaft. For instance, where gravels are above London Clay, a caisson could be used for the gravel section, followed by underpinning or sprayed concrete lining in the London Clay.

3.3.14 The construction methods for connection tunnels are covered in Section 4 on tunnels.

3.3.15 Opportunities to co-locate CSO interception works with main tunnel sites are considered at the stage of moving from the shortlist of sites to preferred sites.

3.3.16 The activities and facilities required for CSO interception sites can be divided into core activities and ancillary activities which could be located on a site area away from the CSO site. The following list of typical core and ancillary activities is illustrative and not exhaustive:

**Core activities**

a. Space to build the interception chamber over and adjacent to the existing sewer, penstock/valve chambers, connection culvert, ventilation structures and drop shaft

b. Primary crane and secondary crane
c. Generator, compressor and diesel tank
d. Pipe-jack machine control cabin (if the site is a pipe-jack drive site)
e. Pipe store, slurry pipe store and bentonite shed (if the site is a pipe-jack drive site)
f. Concrete segment store (if the site is a tunnel boring machine (TBM) drive site)
g. Excavated material handling/storage area for the shaft construction
h. Excavated material handling/storage area for the connection tunnel construction (if the drop shaft is a drive shaft)
i. Access roads and facilities to secure the site

**Ancillary activities**

j. Construction traffic parking

k. Offices and welfare facilities

l. Vehicle and pedestrian circulation areas

m. Workshop.
Transport of materials

3.3.17 CSO sites vary in size and situation. In most cases, the number and nature of the deliveries to and from the sites would be relatively small, compared to the main tunnel drive sites.

3.3.18 For CSO sites, materials would be transported by road.

Site size

3.3.19 CSO site areas are expected to range in size due to the following factors:

a. The location and size of the interception structures (e.g., interception chamber, valve chamber, ventilation structures and connection culvert).

b. Physical constraints presented by the existing layout, such as proximity of buildings, other surface structures and underground infrastructure.

c. The location of access/egress available to the site, and ensuring that there is sufficient area to move vehicles to avoid conflicts with people and other vehicles.

d. Where there is a group of CSO sites close together, ancillary items such as welfare facilities can be shared by being located at only one of the sites in the group. This allows the other sites in the group to have smaller site areas.

e. The drop shaft diameter and depth.

f. The ground conditions and hence method of construction of the drop shaft. If the drop shaft needs to be constructed using diaphragm walling, the area would be larger than if other shaft construction techniques are used.

g. If the drop shaft is used as a tunnel reception shaft, the area would be smaller than CSO sites where the drop shaft is used as a drive shaft for the connection tunnel.

h. The size of the connection tunnel where the drop shaft is used as a drive shaft for the connection tunnel.

i. The ground conditions, and hence method of construction, of the connection tunnel where the drop shaft is used as a drive shaft for the connection tunnel. If the connection tunnel is constructed using a slurry TBM, such as in Chalk ground conditions, larger excavated material handling facilities are required.

j. Where the connection tunnels are pipe-jacked, the CSO site area would be smaller than that of a TBM-driven tunnel site.

3.3.20 The largest CSO site areas would be those where the drop shaft is large, deep, used as a drive shaft, is constructed using diaphragm wall techniques, and where the connection tunnel is large and is in Chalk so a slurry TBM is required.
3.3.21 The smallest CSO site areas would be those where the drop shaft is small, not deep, is used as a reception shaft and is not constructed using diaphragm wall techniques.

3.3.22 CSO site size requirements would vary depending on the combination of circumstances at each site. In order to provide space for both core and ancillary activities, it is anticipated that CSO sites, where drop shafts need to be constructed in London Clay/Lambeth Group/Thanet Sand Formation, may need to range from 1,500m$^2$ for reception sites to 5,000m$^2$ for sites where drop shafts are constructed by diaphragm wall techniques. In Chalk ground conditions, CSO sites may need to range from 1,500m$^2$ to 7,500m$^2$ as the excavated material handling facilities require larger areas. However, if all the circumstances in Paragraph 3.3.20 occur, the site area would need to be approximately 12,000m$^2$.

3.3.23 Site sizes may conceivably be smaller if no suitable sites are available that match these guidelines, but the smaller the site, the more constrained the construction activities become, with potential to adversely affect factors including transport of materials, construction periods, cost, and health and safety mitigation.

3.3.24 A CSO site layout with a site area of 1,500m$^2$ is indicated in Figure 3.2. Note that the ‘rectangular’ shape in plan is indicative only as individual site boundaries and constraints will affect the layout of facilities needed at each site. CSO sites requiring areas of 5,000m$^2$ or 7,500m$^2$ would need similar layouts to the main tunnel reception sites illustrated in Section 4.6.

**Figure 3.2 Example of a CSO site layout, site area 1,500m$^2$**

3.4 CSO Sites – operational phase

3.4.1 The operational phase is the period after construction when the new CSO control system is working, ie, the equipment and structures would be operated and maintained.
3.4.2 It is anticipated that the following air management ventilation structures would be required:

a. All CSO sites would require an interception chamber ventilation column approximately 6m high.

b. Most CSO sites would require a passive filter chamber comprising below-ground odour treatment equipment.

c. Most CSO sites would require an above-ground ventilation structure, approximately 4m high, to control air movement out of and into the drop shaft and tunnels. Architectural design will influence whether this is provided as a single wider structure or a series of narrower structures.

d. Some CSO sites would require a ventilation building (to house active mechanical ventilation plant for air extraction/intake and air treatment/odour control) and a ventilation column, approximately 15m high.

3.4.3 All CSO sites would require the following:

a. Space adjacent to the drop shaft to provide an access point to accommodate mobile cranes for moving people and materials in and out for inspections and maintenance.

b. Adequate access from the highway to allow cranes and other vehicles to enter the site. Access routes/areas could be shared with others or be part of the existing road network.

c. An electrical and control kiosk to house the telemetry communications unit and control equipment for the underground penstocks and ancillary equipment.

d. CSO interception chambers would be finished at ground/road level. The top structure of drop shafts, and possibly valve chambers, may need to be at about 104.5m above tunnel datum (ATD) (equivalent to 4.5m above Ordnance Datum (AOD)) and therefore could be visible above ground level, depending on existing ground levels. Interception chambers, valve chambers and drop shafts would have manhole covers. All drop shafts may have manhole covers capable of being accessible by mobile cranes so that periodic inspections can be carried out.

3.4.4 Thames Water operational personnel would require access periodically for inspection and maintenance purposes. It is anticipated that this would include:

a. connection tunnel and drop shaft inspections, once every ten years (the first inspection within the first few years of operation is possible)

b. equipment inspections or maintenance (eg, ventilation equipment, penstocks) once every three to six months. Such equipment would be located in chambers or connection culverts and not deep drop shafts

c. visits for unplanned maintenance or repairs; for example, if there is a blockage or equipment failure.
3.4.5 Due to the depth of the drop shafts, for health and safety reasons, access into the shafts would be via man-riders lowered from cranes. Man-riders are cages that are specifically designed for people to stand in while they are moved by crane.

3.4.6 Depending on the length of the connection tunnels, it may be necessary to provide ‘safety access points’ on the longer connection tunnels to ensure a safe distance between access/egress points.
4 Tunnels

4.1 Main tunnel components

4.1.1 For the CSOs where direct interception would be required, the objectives for the main tunnel are to collect, store and transfer the intercepted flows for treatment at Beckton STW.

4.1.2 The tunnel components include:
   a. shafts on the main tunnel
   b. the main tunnel
   c. CSO connection tunnels.

4.1.3 It is anticipated that two types of sites would be required to construct and operate the main tunnel and its shafts, comprising:
   a. main tunnel drive sites
   b. main tunnel reception sites.

4.1.4 Main tunnel intermediate sites may also be required.

4.1.5 The CSO connection tunnels would be constructed and operated from either main tunnel sites or CSO sites.

4.1.6 A main tunnel drive site would be used to install and then drive the TBM (the tunnel construction method is described from Paragraph 4.2.8) and hence deal with excavated material, all support facilities for the TBM and the primary lining of the main tunnel. It would also provide access for secondary lining installation, should this be required (secondary lining is described from Paragraph 4.2.6).

4.1.7 A main tunnel reception site would be used to remove the TBM from the tunnel at the end of a drive. It would also provide access for installing secondary lining, should this be required.

4.1.8 The TBM would drive through an intermediate shaft. A main tunnel intermediate site would be used to gain access to the tunnel bore during construction, either to inspect and/or maintain the TBM, or to provide access for installing a secondary lining, should this be required.

Main tunnel shafts (drive and reception)

4.1.9 All main tunnel shafts would need to be excavated down to the level at which the tunnel is to be driven.

4.1.10 Main tunnel sites with drive shafts require more space than those with reception shafts. This is because drive shafts are used to:
   a. install the TBM in the tunnel
   b. extract and store excavated material from the tunnel until it is transported elsewhere
   c. store and supply tunnel segments for the primary concrete tunnel lining
d. provide access for the workforce.

4.1.11 Reception shafts, on the other hand, are used to remove the TBM from the tunnel and have no need for space to store tunnel excavated material or tunnel segments.

4.1.12 Both the main tunnel drive and reception shafts are anticipated to range typically from 20m to 25m in internal diameter, but may be 30m. The internal diameter would be sized to ensure that the connection between the shaft and the main tunnel is structurally sound, and that the entry and exit of the construction equipment, such as the TBM, can be safely accommodated. The larger 30m diameter may be needed if the shaft receives flows from CSO connection tunnels, in order to incorporate the hydraulic vortex structures to drop the flow down the shafts, or if the shaft has to service double tunnel drives.

4.1.13 The number of tunnel drives and the number and type of shafts on the main tunnel would be dependent on the following factors:

a. Programme constraints.

b. Differing geological ground conditions expected. Matching TBMs to ground conditions increases productivity and minimises risk. It is likely that a slurry machine would be more suited to Chalk conditions and an earth pressure balance (EPB) machine more suited to London Clay conditions.

c. Length of drives and the risk of TBM breakdowns (the severity and frequency of breakdowns increase with the length of the drive).

d. Health and safety reasons associated with emergency egress of the workforce.

4.1.14 The number of TBMs, and hence the number of main tunnel drive and reception sites actually needed, would be based on a balance between type of TBM, available location of main tunnel sites, geology, programme, environment, amenity, health and safety, risk, and cost considerations.

4.1.15 Construction of CSO connection tunnels would, where possible, be constructed from main tunnel drive or main tunnel reception sites. This means that the associated CSO site would then act as a smaller CSO reception site to receive the connection tunnel instead of a larger CSO drive site.

4.1.16 Main tunnel drive and reception shafts are lined with concrete and may be constructed in different ways, as described for CSO drop shafts (see Paragraph 3.3.11).

Intermediate shafts

4.1.17 For a tunnel, there would be a drive shaft and a reception shaft, ie, a shaft at either end of the tunnel. There may be no need for an intermediate shaft, however they could be needed to:

a. gain access to undertake planned inspections of TBM faces partway along tunnel drives to allow repairs in safe conditions
b. provide access to the tunnel to install secondary lining, should this lining be needed

c. connect a CSO connection tunnel to the main tunnel via a shaft

d. provide a permanent access point to the main tunnel if the distance between the drive shaft and reception shaft access points are considered too long, and there are no CSO drop shafts that could be used to access the main tunnel.

4.1.18 By undertaking secondary lining from intermediate shafts as well as from other shafts, the tunnel would be completed earlier than if only shafts at either end of the drive were used and hence reduce overall construction time.

4.1.19 In Chalk ground conditions, it is preferable for CSO connection tunnels to be connected to the main tunnel via a shaft and not via a tunnel-to-tunnel junction.

4.1.20 The intermediate shafts are assumed to range from 20m to 25m internal diameter.

4.1.21 Main tunnel intermediate shafts are lined with concrete and may be constructed in different ways, as described for CSO drop shafts (see Paragraph 3.3.11).

**Potential uses of main tunnel sites**

4.1.22 Main tunnel drive sites could be used in the following combinations:

a. Driving the main tunnel in one direction (single main tunnel drive site).

b. Driving the main tunnel in one direction and receiving the main tunnel from the opposite direction (single main tunnel drive site).

c. Sequentially driving the main tunnel in two directions – the first drive would be completed before the second drive started (single main tunnel drive site).

d. Concurrently driving the main tunnel in two directions (double main tunnel drive site).

e. Any of the above, with the driving or receiving of one or more CSO connection tunnels.
4.1.23 Main tunnel reception sites could be used in the following combinations:
   a. Receiving the main tunnel from one direction.
      ![Diagram]
   b. Receiving the main tunnel from two directions.
      ![Diagram]
   c. Either of the above, with the driving or receiving of one or more CSO connection tunnels.

4.1.24 Main tunnel intermediate sites could be used in the following combinations:
   a. Driving the main tunnel straight through the shaft.
      ![Diagram]
   b. As above, with the driving or receiving of one or more CSO connection tunnels.

4.1.25 These sites need to be able to satisfy construction requirements (ie, allow the project to be built) and operational requirements (ie, enable the completed project to be operated and maintained).

**Common features**

4.1.26 During construction, the sites would host various construction activities that are required to build the facility, and such activities dictate the requirements for site size. Site activities and facilities can be divided into core activities and ancillary activities. Space for core activities is essential at each site and space for ancillary activities would ideally be located at the same site, but could be located at another site remote from the principal site if the ancillary site is within a reasonable distance.

4.1.27 Site layouts would be configured to reflect local constraints. Devising possible layouts for individual sites is carried out when sites have been shortlisted, and these layouts would be finalised by the contractor to suit its method of working, subject to any controls on layout imposed through the planning submission and approval process.

4.1.28 If sites of sufficient size are not available or identified, it may be possible to link two smaller sites. It is less desirable to have two smaller linked sites for logistical reasons, as it may generate more pedestrian and vehicular movements and, potentially, more effects on the area between and/or adjacent to the two separate locations. Possible site configurations and combinations of sites form part of the consideration of shortlisted sites for the selection of preferred sites.
4.2 **Main tunnel**

**Main tunnel horizontal alignment**

4.2.1 The horizontal alignment of the main tunnel would generally follow the River Thames. This is because:

a. it is an efficient route to connect the CSOs that are located on both the north and south sides of the river

b. it would minimise the physical structures that the tunnel would pass beneath

c. it would minimise the number of third-parties affected by the tunnel

d. it would allow the use of the river for construction transport where practicable and cost-effective.

4.2.2 The main tunnel route would be constructed beneath urban land only to the extent that:

a. shafts on the main tunnel are located inland (so the tunnel would be beneath urban land from river to the shaft and back)

b. it is impracticable to follow the line of the river because there are overriding engineering or environmental constraints along the river alignment

c. it is most practicable, efficient and cost-effective to go across rather than around a peninsula

d. a section of main tunnel runs between Abbey Mills Pumping Station and the River Thames

e. a section of main tunnel runs between Acton Storm Tanks and the River Thames.

**Main tunnel vertical alignment**

4.2.3 The intercepted flows from the CSOs would flow west to east under gravity to Tideway Pumping Station in Beckton STW. Therefore the tunnel is shallower in the west and deeper in the east. The main tunnel would be constructed on a shallow gradient and would be approximately 30m deep at its western end and approximately 65m deep at the eastern end of the Abbey Mills route.

4.2.4 The geology through which the main tunnel traverses changes from west to east and it is expected that:

a. to the west of the Battersea area, the tunnel would be in London Clay

b. between the Battersea area and Tower Bridge, the tunnel would be in mixed material of the Lambeth Group and Thanet Sand Formation (ie, gravels, sand and silty clay)

c. to the east of Tower Bridge, the tunnel would be in Chalk.
4 Tunnels

**Size**

4.2.5 At this stage, it is anticipated that the main tunnel would:

a. extend from Acton Storm Tanks to Abbey Mills Pumping Station
b. be 25km long
c. be 7.2m internal diameter for the majority of the tunnel, but the diameter of the most westerly tunnel drive would be smaller, depending on the length of the most westerly tunnel drive.

**Secondary lining**

4.2.6 At this stage, it is assumed that a secondary lining would be required, but this will be clarified by future design work.

4.2.7 Secondary lining is an additional layer of concrete added to the inside of the tunnel against the face of the primary concrete segment lining. It is placed by erecting shutters within a short length of tunnel and pumping concrete into the gap between the shutter and the primary lining. Once the concrete has hardened enough, the shutters are removed and erected in the next stretch of tunnel.

**Tunnel construction method**

4.2.8 The main tunnel would be constructed using TBMs. The TBMs would start from drive shafts and stop at reception shafts, where TBMs are removed.

4.2.9 A TBM consists of a rotating cutter face, the same diameter as the tunnel, on the front of a steel cylinder (shield) containing drive motors, gearboxes and control equipment. Behind the TBM shield is a series of towed trailers carrying backup equipment and material handling facilities.

4.2.10 As the tunnel is excavated, the primary precast concrete tunnel segmental lining is installed at the back of the shield. The primary tunnel lining consists of a set of concrete segments that are erected to form a complete ring and fastened to the lining segments previously assembled. Grout is injected behind the ring to fill any voids between the concrete segments and the excavated ground surface. The TBM moves forward, using hydraulic rams, thrusting off this newly assembled primary lining.

4.2.11 It is anticipated that two types of TBMs would be used: EPB TBMs and slurry TBMs (diagrams are provided in Figure 4.1 and Figure 4.2 respectively).

4.2.12 With an EPB TBM, the advancing face of the excavation is supported by the previously excavated material within the head of the machine. As the machine advances, the excavated material is removed using a large screw and then transported out of the tunnel, either by conveyor or a train.

4.2.13 With a slurry TBM, as material is excavated, it is mixed with a fluid or slurry circulating back to the ground surface via a pipeline. The face of the excavation is supported by hydraulic pressure from the slurry and the excavated material is removed from the circulating slurry by a treatment plane at the surface.
4.2.14 The selection of type of TBM for a particular tunnel drive depends on the ground conditions to be encountered over that drive. The tunnel would be constructed beneath the water table through varying ground conditions of clay, gravels, sand, silty clay and chalk.

Figure 4.1 EPB TBM diagram

Figure 4.2 Slurry TBM diagram

4.2.15 In each case, excavated material or slurry would be passed back from the tunnel face to the drive shaft, either by conveyor, pipeline or by a railway system. Tunnel lining materials would be passed forward to the tunnel face from the drive shaft by a railway system. Therefore, the majority of site logistics for main tunnel drive sites are associated with the delivery of the tunnel lining segments and the removal of the excavated materials.

4.2.16 The type of TBM to be used for a particular drive would have implications for the drive site which serves it, because the site set-up must handle excavated material in the form that it is removed from the face of the TBM. For example:

a. An EPB machine produces excavated material that is dryer than a slurry machine and can be removed from the tunnel by either conveyor or construction train.
b. With a slurry TBM, slurry (usually bentonite) is supplied to the excavated face, where it both supports the face of the ground and combines with the excavated material to allow it to be pumped to the surface. The pumped mixture is then treated, by a processing plant, to separate the slurry from the excavated material, such that the excavated material can be removed from site.

4.2.17 TBMs require large electrical power supplies to be provided to the site. It is currently expected that this supply would be provided from the local electrical high-voltage supply network, which may need new substations at some locations to meet the power requirements of this project.

4.3 CSO connection tunnel

4.3.1 CSO connection tunnels are expected to range from 2.2m to 5m internal diameter. The minimum internal diameter to allow access and inspection is 2.2m. The long and larger diameter connection tunnels are expected to be constructed using TBMs, ie, constructed in the same way that the main tunnel would be constructed, but using smaller diameter TBMs.

4.3.2 For short connection tunnels in cohesive ground conditions, it may be appropriate to install sprayed concrete linings rather than concrete segments, or to use a different construction technique, such as traditional hand-dig methods.

4.3.3 Smaller connection tunnels of less than 2.5m internal diameter may be constructed using pipe-jacking techniques.

4.3.4 The pipe-jacking technique uses a small slurry or EPB TBM to excavate the ground. However, instead of the lining being constructed from segments immediately behind the TBM, whole concrete pipes are in-line at the drive shaft and the entire pipe string is ‘jacked’ (pushed) forward, using steerable, remote controlled, hydraulic rams located at the bottom of the shaft. The jacking force propels the TBM and installs the pipe. During tunnelling, bentonite slurry is injected along the line of the pipe as lubricant. When tunnelling is completed, grout is injected to support the ground.

4.4 Main tunnel drive sites – construction phase

Purpose

4.4.1 The main tunnel drive sites are required for constructing the main tunnel and would be used to facilitate:

a. construction of the drive shaft
b. assembly of TBMs at the beginning of tunnel sections
c. construction of the main tunnel
d. removal of excavated material in solid or slurry form from the tunnel
e. short-term storage of excavated material
f. short-term storage of material such as concrete segments for primary tunnel lining
g. access to the tunnel for workers during construction  

h. ventilation for workers in the tunnel  

i. pumping out any water ingress from the tunnel during excavations  

j. connection to a power supply for the TBM and other underground construction equipment  

k. access for secondary lining construction, if required  

l. permanent access to the tunnels when the project is operational  

m. possible CSO connection tunnel construction  

n. possible CSO interception works construction.  

**Timing**

4.4.2 It is anticipated that main tunnel drive sites would be required as construction sites for six years (excluding advance works such as utility connections and utility diversions).

**Location**

4.4.3 Engineering requirements for the locations of main tunnel drive sites are that they:

a. are directly above the main tunnel  

b. have ground conditions that are suitable for a shaft of the requisite depth to be constructed safely  

c. optimise the tunnel drive lengths to allow efficient construction (ie, matching drive lengths with TBM type and risks, such as possible breakdowns posed by different ground conditions, and matching drive lengths to points that would be convenient to connect multiple CSOs)  

d. provide an area that can accommodate the construction related activities given in Section 4.4.11  

e. allow opportunities for access to the river for the supply and removal of materials where practicable and cost-effective  

f. are on land, because the size of the main tunnel drive sites required during construction means it would not be practical to accommodate them on platforms entirely in the river, and because the main tunnel drive shaft would be used to provide access to the tunnel network once the system is operational  

g. provide access for construction of the secondary lining, if required  

h. satisfy health and safety requirements regarding safe egress from the tunnel by the workforce in an emergency.  

4.4.4 There are also planning, environmental, community and property considerations which are addressed in the site selection process as set out in the *Site selection methodology paper*.  

Main tunnel site search area

4.4.5 The main tunnel search area applies to all site types: drive, reception and intermediate.

4.4.6 The limit of the search area for the most westerly main tunnel site is in the vicinity of the most westerly of the CSOs to be intercepted, which is the Acton Storm Relief CSO.

4.4.7 The limit of the search area for the most easterly main tunnel site is in the vicinity of Abbey Mills Pumping Station.

4.4.8 The general limit to the width of the site search area was 500m on both the north and south sides of the river, measured from the river edge, because:
   a. the main tunnel is intended to generally follow the route of the river and the shafts on the main tunnel need to be close to the river
   b. the further away from the river that main tunnel sites are located, the more likely it is that the potential benefit of using river transport would be significantly reduced. The opportunity to be able to use the river to transport materials (where practicable and cost-effective) is considered to be an important consideration of the project
   c. the further away from the river that main tunnel sites are located, the more the main tunnel would have to pass under built-up land
   d. it is likely that the CSO interception chambers would be close to the river and there would be interception chambers on both sides of the river, so the closer the main tunnel follows the route of the river, the shorter the CSO connection tunnels would be.

4.4.9 It was, however, recognised that sites outside a 500m limit would be required. The search area was extended to encompass two areas away from the river – the area around Acton Storm Tanks and the area around Abbey Mills Pumping Station – in order to investigate the potential for sites with which to construct the main tunnel on the Abbey Mills route.

Main tunnel drive site activities

4.4.10 Typical activities, facilities and space requirements associated with a main tunnel drive site situated on a single site are illustrated in Figure 4.3 and Figure 4.4.

4.4.11 The following list of typical core and ancillary activities is illustrative and not exhaustive:

Core activities
   a. Construction of the shaft and tunnel
   b. Deliveries of construction materials for shaft excavation, TBM assembly and tunnelling
   c. Storage, treatment and removal of excavated material arising from the shaft excavation and the tunnel excavation
d. Material stockyard for tunnel segments and accessories, including loading/unloading area (double handling would be required if this was not a core activity)

e. Cranage of materials within the worksite into and out of the tunnel shaft

f. Secondary lining equipment, materials and resources, if required

Ancillary activities

g. Where practicable and cost-effective, river access comprising a wharf/jetty to service barges

h. Workshops to maintain all the mechanical and electrical plant, large stores for spare parts, stockyard for rails, pipes, grease, foam/flocculants, cable drums, timber, cooling plant, generators, backup equipment and TBM power supply installations

i. Construction offices, welfare facilities and medical facilities

j. Parking for construction traffic, which would be kept to a minimum in accordance with the Green Travel Plan

k. Incoming and outgoing goods/materials consolidation/marshalling

l. Vehicle and pedestrian circulation areas.

4.4.12 A concrete batching plant for the secondary lining may be required. A concrete batching plant mixes aggregate, sand, cement and water to produce concrete on the site, but an alternative would be to use ready-mixed concrete, delivered to site by concrete mixer lorries. Such a facility would not be required until after tunnel excavation had been completed and therefore would not require additional space, but could be located on site areas released from other completed activities.

Transport of materials

4.4.13 The main tunnel drive sites would be used for construction of the shaft and the main tunnel. It would be necessary to transport excavated material away from the main tunnel drive shaft sites and to deliver a wide variety of materials, including the precast concrete segments for the primary lining of the tunnel. Other logistical activities would include workforce arrival/departure, equipment deliveries/return, consumables delivery and waste removal.

4.4.14 Due to the large volume of materials to be transported, the objectives are to use river transport to:

a. transport main tunnel excavated material where shafts are adjacent to the River Thames

b. import and export backfill material for cofferdam construction

c. enable construction contractors to move other materials by river where practicable and cost-effective.
4.4.15 A barge operation would only be practical if:

a. the material can easily be conveyed between the shaft and the river
b. a staging area can be located at the barge sites
c. the river can accommodate barges of adequate capacity
d. the barge operations would not conflict with other uses and users of the river
e. it is commercially viable.

4.4.16 It is currently assumed that:

a. the main tunnel drive sites are currently anticipated to be near the river and hence such river transport is possible. Where river transport is used, wharfs and/or jetties would need to be able to accommodate barge-type vessels, ideally within a wide tidal range
b. materials delivered to the sites would be transported by road as river transport may not be cost-effective or logistically efficient.

4.4.17 The practicality of rail transportation would depend on the proximity of the main tunnel drive sites to suitable rail sidings and the local network capacity for freight movements.

4.4.18 Highway access routes would be identified as part of the project development for materials delivered to site. Major deliveries/removals would be subject to specific movement restrictions and conditions imposed by the police and traffic authorities.

**Site size**

4.4.19 In order to provide space for both core and ancillary activities, it is anticipated that main tunnel drive sites:

a. from which slurry TBMs would be driven would need approximately 20,000m²
b. from which EPB TBMs would be driven would need approximately 18,000m².

4.4.20 The difference in site size is due to the excavated material handling activity of EPB TBMs requiring less space than that for a slurry TBM.

4.4.21 These approximate site areas have been based on assumptions concerning tunnelling construction rates, working hours, excavated material processing requirements, excavated material storage duration and concrete segment storage duration.

4.4.22 These areas assume that all facilities would be provided on one site and on land. Structures and storage areas would generally be low-level buildings, with cranes being the only high feature. If core and ancillary activities are spilt across two sites, it is likely that the combined area would be larger.

4.4.23 If the activities have to be constrained onto a smaller site, this could be accommodated by raising the height of buildings and structures, and by reducing the time that excavated material is stored on site. For example,
by adopting such measures, a main tunnel drive site from which an EPB TBM would be driven could reduce in size from approximately 18,000m² to approximately 15,000m². However, the more constrained construction activities become, the more likely there would be adverse impacts on factors such as transport of materials, construction periods, cost, and health and safety.

4.4.24 Typical areas used for the slurry TBM and EPB TBM site set-ups are indicated in Figure 4.3 and Figure 4.4 respectively. Note that the ‘rectangular’ shape in the plan is indicative only as individual site boundaries and constraints will affect the layout of facilities needed at each site.

Figure 4.3 Main tunnel drive site for a slurry TBM, site area 20,000m²
4.4.25 It may be necessary to drive the main tunnel in two directions from the same location where the tunnel would either be:

a. tunnelled in one direction first and the other direction second (ie, sequentially)
b. tunnelled in both directions at the same time (ie, concurrently).

4.4.26 If tunnelled sequentially:

a. the site size would be the same as a single main tunnel drive site, because only one tunnel would be constructed at a time
b. the construction duration would be longer as the second tunnel would start after the first tunnel had been excavated.

4.4.27 If tunnelled concurrently:

a. the site size would be larger than a single main tunnel drive site, because two tunnels would be constructed at the same time
b. the construction duration would be longer as the tunnels would not start together, but the duration would be shorter than if the tunnels are constructed sequentially.

4.4.28 If double main tunnel drive sites are required, then consideration would be given to sharing facilities in order to reduce the overall site area required, and to making the most efficient use of transportation facilities to minimise disruption from delivery and removal operations.
4.4.29 Depending on the potential for facilities to be shared, double main tunnel drive sites could range in size from 20,000m$^2$ in space constrained areas using one contractor, to 40,000m$^2$ in unconstrained areas using more than one contractor.

4.5 **Main tunnel sites – operational phase**

4.5.1 The structures and equipment required at main tunnel sites for the operational phase is not dependent on whether the site is used as a drive, reception or intermediate site at the construction phase.

4.5.2 It is anticipated that the following air management structures would be required:

a. Most main tunnel sites would require a passive filter chamber comprising below-ground odour treatment equipment.

b. Most main tunnel sites would require an above-ground ventilation structure, approximately 4m high, to control air movement out of and into the shaft and tunnels. Architectural design will influence whether this is provided as a single wider structure or a series of narrower structures.

c. Some main tunnel sites would require a ventilation building (to house active mechanical ventilation plant for air extraction/intake and air treatment/odour control) and a ventilation column, approximately 15m high.

4.5.3 All main tunnel sites would require the following:

a. Space adjacent to the shaft would be required to accommodate mobile cranes for moving people and materials in and out of the shaft for inspections and maintenance.

b. Adequate access from the highway to allow cranes and other vehicles to enter the site. Access routes/areas could be shared with others or be part of the existing road network.

4.5.4 The top structure of shafts may need to be about 104.5mATD (4.5mAOD) and therefore could be visible above ground level, depending on existing ground levels. All shafts may have manhole covers capable of being accessible by mobile cranes so that periodic inspections can be carried out.

4.5.5 Thames Water operational personnel would require access periodically for inspection and maintenance purposes. It is anticipated that this would include:

a. main tunnel and shaft inspections once every ten years

b. equipment inspections or maintenance (eg, ventilation equipment, penstocks) once every three to six months. Such equipment would be located in chambers and not deep drop shafts

c. visits for unplanned maintenance or repairs; for example, if there is a blockage or equipment failure.
Due to the depth of the shafts, for health and safety reasons, access into the shafts would be via man-riders lowered from cranes.

**Main tunnel reception sites – construction phase**

**Purpose**

4.6.1 Main tunnel reception sites would be used to facilitate:

a. construction of the reception shaft

b. dismantling and removal of TBMs at the end of tunnel sections

c. access for secondary lining construction, if required

d. possible CSO connection tunnel construction

e. permanent access to the tunnels when the project is operational.

**Timing**

4.6.2 It is anticipated that main tunnel reception sites would be required as construction sites for four to five years (excluding advance works such as utility connections and utility diversions).

**Location**

4.6.3 Engineering requirements for the locations of main tunnel reception sites are that they:

a. are directly above the main tunnel

b. have ground conditions which are sufficiently good for a shaft of the requisite depth to be constructed safely

c. optimise the tunnel drive lengths to allow efficient construction

d. provide an area that can accommodate the construction related activities given in Section 4.6.6

e. are on land, because the shaft would be used to provide access to the tunnel network once the system is operational

f. provide access for construction of the secondary lining, if required

g. satisfy health and safety requirements regarding safe egress from the tunnel by the workforce in an emergency.

4.6.4 There are also planning, environmental, community and property considerations, which are addressed in the site selection methodology and process as set out in the *Site selection methodology paper*.

**Main tunnel reception site activities**

4.6.5 Typical activities, facilities and space requirements associated with a main tunnel reception site situated on a single site are illustrated in Figure 4.5 and Figure 4.6.
4.6.6 The following list of typical core and ancillary activities is illustrative and not exhaustive:

**Core activities**

a. Construction of the shaft  
b. Delivery of construction materials for shaft excavation and TBM removal  
c. Storage, treatment and removal of excavated material arising from the shaft excavation  
d. Cranage of shaft excavation material and workforce access  
e. Secondary lining equipment, materials and resources, if required

**Ancillary activities**

f. Workshop and stores  
g. Construction office, parking and welfare facilities  
h. Vehicle and pedestrian circulation areas.

4.6.7 If secondary lining is required, a concrete batching plant for secondary lining may be used instead of ready-mix concrete. Such a facility would not be required until after shaft excavation was completed and therefore would not need additional space.

**Transport of materials**

4.6.8 River transport at main tunnel reception sites is not likely as the volume of materials handled at these sites would be much lower than at main tunnel drive sites. This is because neither excavated material from the tunnel nor primary lining concrete segments would be handled at main tunnel reception sites. However, the opportunity for barge facilities at such sites would be considered.

4.6.9 Deliveries and shaft excavated material are expected to be transported by road, and the highway access routes would be developed as part of the project development.

**Site size**

4.6.10 In order to provide space for both core and ancillary activities, it is anticipated that an area approximately 7,500m² would be required for main tunnel reception sites where shafts need to be constructed in Chalk ground conditions. For other ground conditions, sites would need to be approximately 5,000m².

4.6.11 More space is required for sites where shafts are constructed in Chalk ground conditions, because the shaft is likely to be constructed using the diaphragm wall technique, which takes more space than other shaft construction techniques.

4.6.12 Typical areas used for the above activities are indicated in Figure 4.5 and Figure 4.6. Note that the ‘rectangular’ shape in the plan is indicative only
as individual site boundaries and constraints will affect the layout of facilities needed at each site.

**Figure 4.5 Main tunnel reception site, site area 7,500m²**

![Diagram of main tunnel reception site, site area 7,500m²]

**Figure 4.6 Main tunnel reception site, site area 5,000m²**

![Diagram of main tunnel reception site, site area 5,000m²]

### 4.7 Main tunnel intermediate sites – construction phase

**Purpose**

4.7.1 If required, intermediate sites for the main tunnel would be used to facilitate:

a. construction of the intermediate shaft

b. planned inspections and maintenance of the TBMs

c. access for secondary lining construction
d. possible CSO connection tunnel construction  
e. possible access to the tunnels when the project is operational.

**Timing**

4.7.2 It is anticipated that main tunnel intermediate sites would be required as construction sites for four to five years (excluding advance works, such as utility connections and utility diversions).

**Location**

4.7.3 Engineering requirements for the locations of main tunnel intermediate sites are that they:

a. are directly above the main tunnel  
b. have ground conditions which are sufficiently good for a shaft of the requisite depth to be constructed safely  
c. enable strategic inspection and maintenance points for the TBM  
d. provide an area that can accommodate the construction related activities given in Section 4.7.6  
e. provide access for construction of the secondary lining  
f. satisfy health and safety requirements regarding safe egress from the tunnel by the workforce in an emergency.

4.7.4 There are also planning, environmental, community and property considerations, which were addressed in the site selection process as set out in the *Site selection methodology paper*.

**Main tunnel intermediate site activities**

4.7.5 Typical activities and facilities associated with main tunnel intermediate sites are illustrated in Figure 4.7 and Figure 4.8.

4.7.6 The following list of typical core and ancillary activities is illustrative and not exhaustive:

**Core activities**

a. Construction of the shaft  
b. Delivery of construction materials for shaft excavation and TBM maintenance  
c. Storage, treatment and removal of excavated material arising from the shaft excavation  
d. Cranage of shaft excavated material and workforce access  
e. Secondary lining equipment, materials and resources, if required

**Ancillary activities**

f. Workshop and stores  
g. Construction office, parking and welfare facilities
h. Vehicle and pedestrian circulation areas.

4.7.7 A concrete batching plant for secondary lining may be required instead of using ready-mix concrete. Such a facility would not be required until after shaft excavation was completed and therefore would not need additional space.

**Transport of materials**

4.7.8 The transport of materials for main tunnel intermediate sites would be similar to those for main tunnel reception sites.

**Site size**

4.7.9 The site size requirements for main tunnel intermediate sites would be similar to those for main tunnel reception sites, ie, for intermediate sites where shafts are constructed in Chalk ground conditions, the area would need to be approximately 7,500m²; for ground conditions other than Chalk, the site would need to be approximately 5,000m².

4.7.10 Typical areas used for the above activities are indicated in Figure 4.7 and Figure 4.8. Note that the ‘rectangular’ shape in the plan is indicative only as individual site boundaries and constraints would affect the layout of facilities needed at each site.

**Figure 4.7 Main tunnel intermediate site, site area 7,500m²**

![Figure 4.7 Main tunnel intermediate site, site area 7,500m²](image)
4.8 Change in site selection nomenclature

4.8.1 There are potentially three types of sites required to construct the main tunnel:
   a. Main tunnel drive sites
   b. Main tunnel reception sites
   c. Main tunnel intermediate sites.

4.8.2 Sections 4.4 to 4.7 show that the site area requirements and site activities are similar for main tunnel reception sites and main tunnel intermediate sites. Therefore, the site selection methodology was used to identify and shortlist two different types of main tunnel sites:
   a. Main tunnel drive sites
   b. Main tunnel reception/intermediate sites.

4.8.3 At the start of the site selection process, these two site types were termed:
   a. ‘main shaft sites’ (later termed ‘main tunnel drive sites’)
   b. ‘intermediate shaft sites’ (later termed ‘main tunnel intermediate sites’ and also applicable for ‘main tunnel reception sites’).