Thames Tideway Tunnel
Thames Water Utilities Limited

Development Consent Order

Application Reference Number: WWO10001

Documents for Certification
September 2014

We, Lindsay Speed and Sarah Fairbrother hereby certify that this is a true copy of the environmental statement referred to in Article 61 (1) (f) of the Thames Water Utilities Limited (Thames Tideway Tunnel) Order 2014.

Lindsay Speed   Sarah Fairbrother

September 2014

Thames Tideway Tunnel
Creating a cleaner, healthier River Thames

Thames Tideway Tunnel
Thames Water Utilities Limited

Application for Development Consent

Application Reference Number: WWO10001

Environmental Statement

Doc Ref: **6.2.03**

Volume 3: Project-wide effects assessment

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

Hard copy available in

Box **17** Folder **A**
January 2013

Thames Tideway Tunnel
Creating a cleaner, healthier River Thames

This page is intentionally blank

Thames Tideway Tunnel

Environmental Statement

Volume 3: Project-wide effects assessment

Errata

Section	Paragraph No.	Page No.	Errata / Clarification
Section 12 Transport	12.2.33(h)	12	Text should read "the adoption of best practice measures for construction road transport, such as the use of vehicles compliant with EURO 6 emission standards, vehicles to be fitted with 'active' cycle safety measures and membership of the TfL Freight Operator Recognition Scheme (FORS)".
Section 14 Water resources – surface water	14.6.10 (Vol 3 Table 14.6.4)	26	The % change from base case figures should be read as negative values ie, -94, -86, -90.

This page is intentionally blank

Thames Tideway Tunnel

Environmental Statement

List of contents

This page is intentionally blank

Thames Tideway Tunnel

Environmental Statement

Volume 3: Project-wide effects assessment

List of contents

Thames Tideway Tunnel

Environmental Statement

Volume 3: Project-wide effects assessment

Sections 1 to 3: Introduction, project context and proposed development

List of contents

Page number

List of plates

Page number

List of tables

Page number

Thames Tideway Tunnel
Thames Water Utilities Limited

Application for Development Consent

Application Reference Number: WWO10001

Environmental Statement

Doc Ref: **6.2.03**

Volume 3: Project-wide effects assessment

Section 1: Introduction

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

Hard copy available in

Box **17** Folder **A**
January 2013

Thames Tideway Tunnel
Creating a cleaner, healthier River Thames

This page is intentionally blank

1 Introduction

1.1 Overview

1.1.1 This volume of the *Environmental Statement* of the Thames Tideway Tunnel project presents the results of the environmental impact assessment (EIA) of the proposed development at the project-wide level.

1.1.2 Given the extent and nature of the project, with multiple sites being required for its construction and operation, significant environmental effects are likely to be experienced over an area which is wider than the immediate vicinity of each individual development site.

1.1.3 The assessment of project-wide effects has considered both beneficial and adverse effects which are likely to arise during the construction and operation of the project as follows:

a. effects likely to be experienced over a wider geographical area than those identified and reported at individual site level such as effects on the wider London transport network as a result of construction traffic

b. effects arising from tunnelling activities experienced along the route of the main tunnel and connection tunnels, such as effects on historic listed buildings and structures as a result of ground settlement.

1.1.4 Effects of multiple Thames Tideway Tunnel project sites where the sites are in close proximity, often termed ‘compound effects’, have been considered within the individual site assessments (see Vols 4 to 27) rather than provided separately or as part of the cumulative effects assessment.

1.1.5 In order to ensure that project-wide effects (as defined in para. 1.1.3) and effects at each individual site are properly assessed and reported, it is appropriate to present the detailed assessments of these effects separately within the *Environmental Statement.* As such, project-wide effects are reported in this volume (Vol 3) and site-specific effects are reported in Vols 4 to 27.

1.1.6 In order to facilitate the decision making process and enable the totality of likely significant effects across the sites to be readily understood, significant effects (prior to mitigation) have been grouped together and tabulated on a topic by topic basis. This has been applied to all topics, including those which have been ‘scoped out’ of the project-wide assessment, namely terrestrial ecology, land quality and townscape and visual (see Sections 4 to 15 of this volume). To allow information to focus on significant effects, minor and negligible effects (non-significant) have not been included. This also allows key information to be presented in a readily accessible form to those whose primary interest relates to an individual site (or collection of sites). Full information on site-specific assessments can be found in Vols 4 to 27.

1.1.7 This section describes the process followed for defining the scope of the project-wide assessment and the general approach to the assessment of project-wide effects. Project-wide issues associated with climate change, use of natural resources and excavated materials and waste are also considered in this section.

1.1.8 The overall project and environmental context is described in Section 2.

1.1.9 Section 3 provides an overview of the proposed development, including a detailed description of those elements of the project which cover a wider geographical area, namely the main tunnel, Frogmore and Greenwich connection tunnels. Detailed information on the proposed works at individual sites, including short connection tunnels, shafts and combined sewer overflow (CSO) interception works, is provided in the site assessment volumes (see Vols 4 to 27) and therefore has not been replicated within this volume.

1.1.10 Section 3 also identifies other major developments which have been considered within the assessment of project-wide effects (in addition to those schemes identified within 1km of each site and which are described in Vols 4 to 27).

1.1.11 Sections 4 to 15 present the project-wide assessment for each environmental topic in alphabetic order.

1.1.12 Figures and appendices for this volume are appended separately (Vol 3 Project-wide effects assessment figures and Vol 3 Project-wide effects assessment appendices). In addition, there is a separate glossary and abbreviations document which explains technical terms used within this assessment.

1.2 Scope of project-wide assessment

1.2.1 A combination of feedback from the EIA scoping exercise and the *Preliminary Environmental Information Report (PEIR)*[i] (Thames Water, 2011)[1] together with comments received as part of the overall engagement process with stakeholders and professional judgement have been used to identify and evaluate the project-wide environmental effects.

1.2.2 Vol 2 Environmental assessment methodology, documents the overall engagement which has been undertaken in preparing the *Environmental Statement*. Vol 3 Table 1.2.1 below presents specific comments from stakeholders in relation to the proposed approach for the assessment of project-wide effects.

1.2.3 Specific comments relevant to the project-wide assessment of effects on individual topics are presented in Sections 4 to 15 of this volume.

---

[i] The EIA process has progressed considerably since the publication of the *Preliminary environmental information report* and the *PEIR* has effectively been superseded by this *Environmental Statement*. The *PEIR* is nevertheless available on the Thames Tideway Tunnel consultation website.

Vol 3 Table 1.2.1 Project-wide stakeholder comments

Consultee	Comment	Response
Infrastructure Planning Commission (IPC) (now the Planning Inspectorate) Section 51 Advice on the Proposed Thames Tunnel *Scoping Report* (Thames Water, May 2011)[2]	The Commission notes the proposed draft structure of the *Environmental Statement* and explanation set out in Sections 5.3 – 5.9 of the *Scoping Report* (Part A). To aid decision-making the Commission suggests that the *Environmental Statement* should **assess and summarise the impacts of the project as a whole**, as set out below addressing all phases of the development, the inter-relationship between each topic and their cumulative effects with other developments.	Construction and operational effects have been assessed at the project-wide scale in Vol 3 and on a site-specific basis in Vols 4 to 27. A summary of significant effects identified at all sites across the project is presented for each topic in Sections 4 to 15 of this volume. The inter-relationships between topics are appropriately signposted and effects on one receptor from two or more topics (eg, air quality and noise effects from a site on residents), often termed 'interactive effects' or 'in combination effects' is inherent within the topic. These are assessed at a project-wide scale in Vol 3 and on a site-specific basis in Vols 4 to 27. Cumulative effects are those that arise from the Thames Tideway Tunnel project with other non-Thames Tideway Tunnel projects. These are assessed at a project-wide scale in Vol 3 and on a site-specific basis in Vols 4 to 27.
	The Commission considers that details should be provided as to how inter-relationships will be assessed in order to address the environmental impacts of the proposal as a whole. This will help to ensure that the ***Environmental Statement* is not a series of separate reports collated into one document**, but rather a **comprehensive**	The *Environmental Statement* provides project-wide and site-specific assessments to reflect the different impacts and effects of the proposed development and the audiences reading the document (see paras. 1.1.5 and 1.1.6).

Consultee	Comment	Response
	assessment drawing together the environmental impacts of the proposed development as a whole. This is particularly important when considering impacts in terms of any permutations or parameters to the proposed development.	
	The Commission considers that the topics identified in the *Scoping Report* encompass those matters identified in Schedule 4, Part 1, paragraph 19 of the 2009 EIA Regulations. However TW's attention is drawn to the possible need to **consider the wider spatial effects** associated with these topics (i.e. beyond the immediate area surrounding the site, downstream for example).	Assessment area varies from topic to topic, and has been identified for both the project-wide and site-specific assessments. The assessment areas are considered sufficiently robust to undertake the assessment. The extent of the assessment area has taken into consideration both recognised professional guidance and stakeholder engagement
	The Commission notes the approach to project-wide impacts within the *Scoping Report*. The Commission considers that in the event of a Development Consent Order (DCO) application being submitted, the **project will be considered as a whole**, rather than a series of related but separate linear schemes assessed on a site by site basis. The Commission suggests that **in assessing the potential environmental project-wide effects the same approach is taken**, and that the **assessment of such effects is presented accordingly within the *Environmental Statement***. The Commission stresses the **importance of ensuring that the *Environmental Statemen*t is not prepared as a series of disparate reports**.	The *Environmental Statement* provides project-wide and site-specific assessments to reflect the different impacts and effects of the proposed development and the audiences reading the document (see paras. 1.1.5 and 1.1.6 and detailed provided above).

Consultee	Comment	Response
	The *Environmental Statement* should also consider in full the inter-relationships between aspects and cumulative impacts associated with the proposed development.	
	The Commission considers that the inter-relationship between aspects of the proposed development should be assessed and that details should be provided as to how inter-relationships will be assessed in order to **address the environmental impacts of the proposal as a whole**.	See previous comment's responses and paras. 1.1.5 and 1.1.6.
Marine Management Organisation (MMO) Phase two consultation report (February 2012)	It is not clear in the phase two consultation documentation where the **impacts of the construction and operation of the main tunnel** will be assessed. The Marine Management Organisation would suggest that **this is covered in the project-wide effects section of *the Environmental Statement*** as the effects are not site-specific due to the nature of the main tunnel and that its route passes under a number of different sites.	The assessment of the effects of main tunnel construction and operation, including noise and vibration and settlement effects on historic structures is provided in Vol 3 Sections 4 to 15.

1.2.4 Vol 3 Table 1.2.2 provides a summary of the aspects that have been considered within the project-wide assessment and identifies where project-wide strategies have been developed to address these aspects.

1.2.5 Scoped in aspects and project-wide issues are discussed in detail in Sections 4 to 15 of this volume.

Vol 3 Table 1.2.2 Scope of project-wide effects assessment

Topic	Considered within project-wide assessment?	Commentary on issues	Where within this volume this is addressed and related application documents
Air quality and odour	✓ (Air quality) ✗ (odour)	Construction works at the project sites would lead to project-wide interactions of construction traffic along major road corridors which could give raise to air quality effects. Project-wide air quality effects during construction have been considered. Site-specific assessments consider odour generated under conditions likely to be encountered during operation. No significant project-wide effects are considered likely for odour. Operational effects have therefore not been assessed at the project-wide level.	Vol 3 Section 4 *Air Management Plan* *Statement in Respect of Statutory Nuisance*
Ecology - aquatic	✓	The proposed development has the potential to affect aquatic ecology receptors throughout the tidal Thames as a result of simultaneous construction of in-river works at foreshore sites across the project. Project-wide effects on aquatic ecology during construction have therefore been considered. Water quality improvements arising from the implementation of the project would generate ecological benefits across the whole tidal Thames. Operational project-wide effects on aquatic ecology have been considered.	Vol 3 Section 5 *Habitat Regulations Assessment: No Significant Effects Report*
Ecology - terrestrial	✗	Effects on terrestrial ecology would mainly relate to habitats and species affected by temporary and permanent land take. Only site-related effects are therefore likely. No construction or operational project-wide effects assessment has	Vol 3 Section 6 *Habitat Regulations Assessment: No*

Topic	Considered within project-wide assessment?	Commentary on issues	Where within this volume this is addressed and related application documents
		been undertaken for terrestrial ecology.	*Significant Effects Report*
Historic environment	✓	Ground settlement generated by tunnelling activities has the potential to affect designated heritage assets. Settlement effects of the main and connection tunnels on heritage assets during construction have been considered at the project-wide level. As ground movement is induced by construction activities, effects are only considered in the construction phase. Operational project-wide effects on designated heritage assets have not been assessed.	Vol 3 Section 7 *Heritage Statement* *Settlement Information Paper*
Land quality	✗	Effects would relate to land conditions at each site. Only site-related effects are therefore likely. No construction or operational project-wide effects assessment has been undertaken in relation to land quality.	Vol 3 Section 8
Noise and vibration	✗ (surface construction and operational effects) ✓ (tunnel construction ground borne	Noise and vibration effects as a result of surface construction activities would be localised and experienced in the vicinity of construction sites and associated haul routes. Surface construction effects have therefore been considered as site-related effects only. Groundbourne noise and vibration effects arising from below-ground activities associated with the main and connection tunnels have been considered and reported on a project-wide basis.	Vol 3 Section 9 *Code of Construction Practice (CoCP)* *Statement in Respect of Statutory Nuisance*

Topic	Considered within project-wide assessment?	Commentary on issues	Where within this volume this is addressed and related application documents
	noise and vibration)	Operational effects would relate to perceived noise in the vicinity of the main and CSO drop shafts and tunnels ventilation equipment and have been considered as site-related effects only. Operational project-wide effects for noise and vibration have not been assessed.	
Socio-economics	✓	The construction of the project would give rise to medium term project wide economic benefits including the creation of construction related employment, enhanced skills within the construction sector workforce and the stimulation of the freight by water sector. Water quality improvements would lead to long term project-wide benefits in supporting increased amenity use of the river and indirectly supporting regeneration (increased system capacity for population growth) and the social effect on improving the position for existing users even if no other users come forward. Socio-economic effects at the project-wide level have been considered during both construction and operation.	Vol 3 Section 10 *Health Impact Assessment (HIA)* *Equalities Impact Assessment (EqIA)* *Employment and Skills Strategy* *Open Space Assessment*
Townscape and visual	✗	Construction and operational effects on townscape and visual receptors are likely to arise close to the individual sites and from key viewpoints in their vicinity. Effects arising from other nearby project sites have been considered within the individual site assessments where necessary. Only site-related effects are therefore likely. No project-wide townscape and visual effects have been assessed.	Vol 3 Section 11

Topic	Considered within project-wide assessment?	Commentary on issues	Where within this volume this is addressed and related application documents
Transport	✓	Project-wide effects on transport may arise from the aggregation of construction-related barges travelling on the River Thames, the aggregation of construction related traffic travelling on the strategic highway network across London and potentially from the combined volume of construction workers using public and private transport to travel to and from the construction sites. Transport activity during operation is expected to be very low and associated with local activities at each site, rather than present any significant activity on the London highway network as a whole. Operational project-wide effects for transport have therefore not been assessed.	Vol 3 Section 12 *Transport Strategy* *Draft Project Framework Travel Plan* *Transport Assessment (TA)*
Water resources – groundwater	✓	The proposed development has the potential to affect groundwater at the project-wide level during construction as a result of dewatering of lower aquifer (Chalk), mobilisation of poor quality groundwater, mixing of groundwater, use of grouts and physical disturbance. Operational effects would relate to physical obstruction of groundwater flows/levels, seepage from/into the main tunnel and the improvement of groundwater quality as a result of reduced pollution. Construction and operational effects on groundwater have been considered at the project-wide level.	Vol 3 Section 13

Topic	Considered within project-wide assessment?	Commentary on issues	Where within this volume this is addressed and related application documents
Water resources – surface water	✓	Construction activities eg, dredging, pilling etc may lead to effects on water quality at the project-wide level as a result of sediment mobilisation. The operation of the Thames Tideway Tunnel project would lead to water quality improvements across the whole tidal reaches of the River Thames (tidal Thames). Construction and operational effects on surface water have been considered during construction and operation.	Vol 4 Section 14 *Statement in Respect of Statutory Nuisance*
Water resources – flood risk	✓	A project-wide flood risk assessment has been undertaken which considers the implications of the project on tidal and fluvial flood risk to surrounding areas through changes in water levels as a result of built footprint in the foreshore, flood defence changes and potential scour. It also identifies the residual risks with respect to flood risk both to and from the project during construction and operation	Vol 3 Section 15 *Resilience to Change*
Climate change	✓	The effects of climate change on the project and conversely the effects of the project on climate change have been embedded within topic assessments where necessary, both at project-wide and site-specific levels. This includes consideration of the latest UK Climate Projections available within topic assessment's modelling eg, surface water and flood risk, as required.	Vol 3 Section 1.4 *Energy and Carbon Footprint Report* (carbon footprint assessment included in Vol 3 Appendix A.2)

Topic	Considered within project-wide assessment?	Commentary on issues	Where within this volume this is addressed and related application documents
			Sustainability Statement *Resilience to Change* (including climate change)
Use of natural resources	✓	The effects resulting from the use of natural resources have been considered, including the use of raw materials, fresh water and land.	Vol 3 Section 1.5 below *Code of Construction Practice (CoCP)* *Sustainability Statement*
Excavated material and waste	✓	The construction of the project would generate a large volume of excavated material which would require removal. The on-site and near-site environmental effects arising from the management, storage and transport of excavated materials and wastes have been considered and assessed as part of the construction effects within each site volume (Vols 4 to 27). The project-wide effects arising from the transportation of these materials to possible receptor sites are considered in Section 1.6 below.	Vol 3 Section 1.6 below *Excavated Materials and Waste Strategy* (see Vol 3 Appendix A.3) *Excavated Materials*

Topic	Considered within project-wide assessment?	Commentary on issues	Where within this volume this is addressed and related application documents
			Options Appraisal (EMOA) (see Vol 3 Appendix A.4) *Statement in Respect of Statutory Nuisance*

✓ *Scoped in*
✗ *Scoped out*

1.3 Approach to assessment of project-wide effects

1.3.1 As noted in para. 1.1.3 the assessment of project-wide effects considers effects likely to be experienced over a wider area than those identified and reported at the site level; as well as effects that would arise from tunnelling activities and which may therefore be experienced under a number of different sites along the project route.

1.3.2 Project-wide effects, as defined in this *Environmental Statement* and explained in Vol 3 Table 1.2.2, have not been identified for all environmental topics. This section provides an overview of the approach followed for the assessment of project-wide effects for those topics which have been scoped in. For those topics which have been scoped out of the project-wide assessment (ie, terrestrial ecology, land quality and townscape and visual), details of engagement have nevertheless been provided where required; together with an overview of the reasons why the topic has been scoped out and a summary of significant effects identified at individual sites where relevant.

Assessment methodology

1.3.3 The general methodology used for the assessment of likely significant environmental effects associated with the project, including project-wide effects, is presented in Vol 2 Section 3.

1.3.4 The specific approach to the assessment of project-wide effects generally varies between different environmental topics (and may differ from the site assessment approach for each topic). The specific approach used to assess project-wide effects for each environmental topic is described in detailed in Vol 2 Sections 4 to 15. These set out how the assessment has been undertaken, including how significance of project-wide effects has been determined, and confirmation of the assessment years and areas considered by each topic.

1.3.5 For each topic, the aspects considered within the assessment and whether construction and / or operational effects have been included is indicated eg, only effects resulting from the construction of underground works have been considered within the noise assessment. Where certain elements have not been included in the assessment eg, operational noise effects, this has been indicated and a justification provided.

1.3.6 The construction and operational elements of the proposed development relevant to the project-wide assessments have been identified and described for each topic. Depending on the scope of the assessment this may relate to the main tunnel itself eg, the depth and construction of the tunnel is likely to be the most relevant aspect for the assessment of effects on groundwater; or to elements at several project sites eg, the presence of temporary and permanent in-river structures is likely to be relevant to the assessment of effects on aquatic ecology.

1.3.7 Specific engagement comments, assumptions and limitations relevant to the assessment of project-wide effects for individual topics have also been detailed where relevant in Sections 4 to 15 of this volume.

Baseline conditions

1.3.8 Existing baseline conditions across the relevant assessment area for each topic have been described and sensitive receptors identified. For some topics, such as aquatic ecology, this includes providing an amalgamation of baseline information collected from several project sites eg, areas of intertidal and subtidal habitat present at each site along the project route.

1.3.9 The anticipated environmental conditions in the year (or years) for which the construction and operational assessments have been carried out (base case) have then been determined. This has taken account of any new sensitive receptors that would be introduced by newly built, partially built or fully operational developments during the considered assessment years.

Temporal scope and assessment years

1.3.10 The temporal scope of the project-wide effects assessment varies from topic to topic depending on when, during the construction and operational periods, significant effects are most likely to happen. For some topics it is considered appropriate to use fixed assessment years eg, Project Year 1 of construction/ Year 1 of operation, whilst for others the assessment has been undertaken throughout longer periods of time eg, entire construction phase. Construction and operational assessment year(s) have been identified for each topic as relevant.

1.3.11 In addition, consideration has been given to the extent to which the construction and operational assessment findings would be likely to be materially different should the programme for the Thames Tideway Tunnel project be delayed by approximately one year.

Embedded measures and mitigation

1.3.12 The assessments have considered embedded measures incorporated into the proposed development to protect the environment and limit disturbance as a result of the project. Embedded measures relevant to the construction phase are contained in the *Code of Construction Practice (CoCP)* (see Vol 1 Appendix A) eg, measures to minimise the impact to third-party infrastructure and buildings as a result of ground movement. For the operational phase, embedded measures (ie, environmental design measures) are set out in the *Design Principles* report (see Vol 1 Appendix B) eg, fendering would be included on foreshore structures where appropriate in order to promote aquatic ecology.

1.3.13 Where the assessments have identified significant adverse effects having taken account of embedded measures (eg, measures within *CoCP* and *Design Principles* report), further mitigation measures have been proposed. In those few instances where adverse significant effects have been identified which cannot be mitigated eg, groundborne vibration effects at receptors with particularly vibration sensitive equipment or processes, compensation measures have been proposed that would offset these significant adverse effects.

1.3.14 A compensation programme, which goes beyond legal requirements, has been established to offset significance adverse construction effects where a receptor is identified to be eligible for compensation. Details of the compensation programme are contained in Schedule 2 of the *Statement of Reasons* which accompanies the application.

1.3.15 In addition, long-term monitoring requirements after the submission of the application for development consent (the 'application') have also been outlined in the topic assessments where necessary.

1.3.16 A summary of project-wide residual construction and operational effects, after taking account of mitigation measures, is provided at the end of Sections 4 to 15.

Cumulative effects assessment

1.3.17 An assessment of cumulative effects at the project-wide level has been undertaken and as explained within Vol 2 Section 3.8, the assessment considers other developments which would be under construction or operational at the same time as the Thames Tideway Tunnel project. A quantitative project-wide cumulative effects assessment has been undertaken whenever possible eg, the strategic modelling work undertaken for the assessment of project-wide transport effects includes allowances for population and employment growth, based on the projections in the *London Plan 2011* (Greater London Authority, 2011)[3], and is therefore inherently cumulative. For those topics where a quantitative assessment is not possible or appropriate, a qualitative evaluation has been carried out using professional judgement to consider whether these other developments would be likely to elevate the project-wide effects identified for the project.

1.3.18 Section 3.5 describes the approach followed for identifying base case and cumulative assessment developments, with details of these other developments included in Vol 3 Appendix A.1.

Summary of significant effects at all sites

1.3.19 As described in Section 1.1, a summary of significant effects identified at the site-specific level across the project is provided for each environmental topic (see Sections 4 to 15 of this volume). Significant effects for the whole project have been brought together in this volume in order to provide key information in an easily accessible format, and facilitate the decision making process.

1.4 Climate change

1.4.1 The *National Policy Statement for Waste Water*, 2012 (NPS) (HM Government, 2012)[4] recognises climate change as posing a major pressure on wastewater infrastructure, and in particular on combined sewer systems, as a result of an increased probability of wetter winters, more intense rainfall events and greater climate variability. Climate change is therefore an acknowledged issue which has driven the design and proposals for construction and operation of the project.

1.4.2 The effects of climate change on the project and conversely the effects of the project on climate change have been embedded within the topic assessments in the *Environmental Statement* where necessary.

Climate change adaptation

1.4.3 Catchment-wide modelling undertaken to inform the design of the project and the assessment of environmental effects has incorporated best available climate change projections for the UK[5] for two future scenarios ie, 2050 and 2080. The results of these modelled scenarios have informed the environmental assessments where necessary, in particular with regards to the surface water and flood risk assessments.

1.4.4 Vol 1 Section 1.3 provides further detail on the approach adopted in this *Environmental Statement* with respect to climate change adaptation.

1.4.5 The *Resilience to Change* report, which also accompanies the application, includes further information regarding the project approach to climate and population changes.

Climate change mitigation

1.4.6 In addition to considering the effects of climate change on the project, the project itself may also have an effect on climate change through energy consumption and the release of CO_2 emissions.

1.4.7 The construction of the project would be an energy intensive process, with significant energy requirements associated with the operation of the tunnel boring machines (TBMs), construction traffic and pumping of dewatering discharges during construction. Energy requirements during operation are anticipated to be considerably lower and associated mainly with the operation of pumps (at Beckton Sewage Treatment Works) and active ventilation systems at three sites.

1.4.8 Opportunities to maximise energy efficiency and minimise the carbon footprint of the project have been considered throughout the development of the proposals.

1.4.9 The proposals to adopt the shortest route alignment from the three options considered during the phase one consultation (see Vol 1 Section 3.5) would lead to direct savings in energy and emissions both during construction and operation. Factors contributing to this include:

a. reduced energy in construction from the operation of TBMs

b. fewer materials required during construction

c. reduced amount of excavated material would be generated requiring transport

d. reduced energy required during operation because of the reduced pumping activities at Beckton Sewage Treatment Works.

1.4.10 Energy consumption and carbon emissions during the construction phase will be minimised through the implementation of an energy management plan, to be produced by the contractor (see *CoCP* Part A Section 10.4).

1.4.11 Energy requirements during operation of the project are anticipated to be approximately 8.5 Gwh per year (see *Energy and Carbon Footprint Report* accompanying the application). These have been minimised through design features such as:

a. main tunnel design – as a result of the proposed gradient the tunnel would be self cleaning, with materials flowing west to east under gravity, reducing the need for purging

b. air management strategy – most of the main tunnel would be ventilated by a passive design, with three new active ventilation sites required for the project's operational phase.

1.4.12 The CO_2 footprint associated with the project's construction and operation has been assessed and is anticipated to be approximately 838,000t CO_2e (see carbon footprint assessment presented in Vol 3 Appendix A.2). The estimated emissions avoided through the implementation of the proposed Abbey Mills route alone are approximately 199,000 tonnes of CO_2e.

1.4.13 Further details of the energy requirements and emissions associated with the project are provided in a separate *Energy and Carbon Footprint Report*, whilst sustainability matters more broadly are covered in the *Sustainability Statement*. Both of these documents accompany the application.

1.5 Use of natural resources

1.5.1 Infrastructure projects such as the Thames Tideway Tunnel project require large quantities of resources to construct including raw materials, water and land. Concrete, grout[ii] and steel would be required to construct the main tunnel, connection tunnels and shafts. Fresh water would be used in construction for concrete and grout production, as well as for various processes such as tunnel boring, wheel washing and dust suppression. In addition, a number of sites would be required to construct and operate the project and this would result in land take.

1.5.2 It is assumed the environmental effects associated with the extraction of materials required for the construction of the project eg, aggregates for concrete, would be addressed through the planning and consenting regime for these activities and have thus not been considered as part of this EIA.

1.5.3 The environmental effects associated with the use of natural resources at specific sites eg, noise impacts from concrete batching activities and the use of foreshore habitat, have been assessed within the individual site assessments (Vols 4 to 27).

1.5.4 This section considers the use of natural resources including raw materials, water and land, during the construction and operation of the project, at the project-wide level.

[ii] A material that is commonly injected in a fluid state to improve the engineering properties of poor ground conditions, fill voids (eg, between a structural tunnel lining and cut ground), or as a material for repairing damaged segments.

Raw materials

1.5.5 The quantities of materials that would be required for the construction of the project are related to its design and performance specifications, and in particular the need to ensure the required durability and structural integrity of the main tunnel.

1.5.6 It is estimated over 1.5 million tonnes of concrete, grout and steel would be required to construct the main tunnel, connection tunnels and shafts. This includes approximately 1.28 million tonnes of concrete, including pre-cast concrete rigs to form the tunnel's main lining, and ready-mix concrete; over 135,000 tonnes of grout for tunnelling and approximately 100,000 tonnes of steel for reinforcing the tunnel.

1.5.7 The construction industry in the UK accounts for the use of 295 million tonnes of virgin material per year[6]. The production of primary (non-recycled) aggregates in the UK in 2010 was estimated at 163 million tonnes[7]; whilst production of crude steel in the UK in 2012 was estimated at 9.5 million tonnes[8]. The material tonnages required for the construction of the Thames Tideway Tunnel would be relatively low in the context of overall usage in the UK and so the project is unlikely to impact the availability of these materials or the environmental impacts associated with their extraction or transport. Given this, no significant effects are anticipated from the use of materials at the project-wide level.

1.5.8 The *CoCP* Part A Section 10.4 identifies a number of measures to promote resource efficiency during construction, including the development of material management plans by contractors to ensure the use of raw materials is minimised eg, use of sustainable sourced materials, recycled or used materials.

1.5.9 The environmental effects of resource use at the sites are addressed in paras. 1.5.2 to 1.5.3 above.

Water consumption

1.5.10 It is anticipated that the majority of water consumption during the construction phase would be at the main tunnel drive sites, due to the nature of activities taking place. It is estimated nearly 60% of the peak water consumption (expected in 2018) would be used for tunnels or shaft concrete and grouting activities. Across the project as a whole, approximately 762,000 l/24 hr of water would be required at the peak of construction. Based on Thames Water's 2011 *Water Resources Management Plan* (Thames Water, 2011)[9], this is equivalent to 0.76 Ml/d, or 0.04% of the total water calculated to be available for London. Given that by 2018 there is estimated to be a supply surplus of 0.8 Ml/d, as a result of the partly completed demand and supply measures being implemented during the water resources plan lifecycle, it is not anticipated that water consumption during construction would have a significant effect on the potable water supply in London.

1.5.11 Water consumption outside of the peak in construction would be considerably less, and once in operation, the project would require minimal water resources. The design of the main tunnel would ensure it is self cleansing, eliminating the need to use water for purging the tunnel using water resources.

1.5.12 In addition to the use of water as an integral part of the construction process, there would also be a need to remove existing raw groundwater to enable the construction of underground structures. Groundwater levels would have to be lower by dewatering to allow the construction of main tunnel and CSO drop shafts within the central and eastern areas. A summary of the anticipated dewatering rates during construction is given in Vol 3 Table 1.5.1.

Vol 3 Table 1.5.1 Anticipated dewatering volumes

Area	Site	Average dewatering volume (m^3/d)
Central	Chelsea Embankment Foreshore	Less than 200
	Kirtling Street	440
	Heathwall Pumping Station	Less than 200
	Albert Embankment Foreshore	Less than 200
	Victoria Embankment Foreshore	Less than 200
	Blackfriars Bridge Foreshore	1,085
Eastern	Chambers Wharf	Less than 200
	King Edward Memorial Park	Less than 200
	Earl Pumping Station	Less than 200
	Deptford Church Street	Less than 200
	Greenwich Pumping Station	Less than 200
	Abbey Mills Pumping Station	Less than 200
	Beckton Sewage Treatment Works	Less than 200

1.5.13 The effects of the proposed dewatering activities on abstraction licence holders have been assessed as part of the EIA and are reported within the groundwater assessments both at the project-wide (see Section 10) and site-specific (Vols 4 to 27) levels.

1.5.14 The *CoCP* Part A Section 8 identifies a number of measures to manage water resources during construction, including a requirement for the contactor to develop *Water management plans*.

Land use

1.5.15 The majority of the project's permanent structures eg, main tunnel and shafts, would be located below ground and therefore would not directly affect surface land use. However, due to the project's length and its linear nature, a number of worksites would be required along the length of the river to facilitate construction and operation of the main tunnel and intercept the CSOs.

1.5.16 The total above-ground area to be used by the project during construction would be approximately 62 hectares. The permanent land take would be substantially less than that required during construction.

1.5.17 The majority of the sites would be located on previously developed (brownfield) land. Furthermore, sites that are required for construction would be reinstated, and permanent land take would be reduced from that required in construction.

1.5.18 In the context of existing land uses in London and given the high proportion of brownfield sites (rather than Greenfield) which would be used and the approach to reinstatement, the land take which would be required for the project during both the construction and operational phases would not generate significant effects at the project-wide level. Effects which may arise in relation to specific considerations related to land use, including socio-economic and ecological effects are covered within the relevant sections of this volume and the site assessment volumes as appropriate.

1.6 Excavated materials and waste

Arisings

1.6.1 The construction activities and in particular the construction of the main and long connection tunnels, as well as the removal of cofferdams, would generate a large volume of excavated material which would require removal. It is anticipated that almost all of the material would be clean, non-hazardous and suitable for re-use and that the only hazardous waste likely to be encountered would be during excavations in the near surface strata at a small number of brownfield sites.

1.6.2 The total amount of material to be removed from all sites across the project is estimated at 4,700,000 tonnes, the main elements of which would comprise:

a. approximately 450,000 tonnes of imported fill for cofferdams (assumed to be clean material and which would require later removal)

b. 130,000 tonnes of mixed materials from diaphragm wall[iii] construction

c. 140,000 tonnes of demolition material

d. 140,000 tonnes of made ground

e. 1,700,000 tonnes of London Clay

f. 940,000 tonnes of the Lambeth group

g. 135,000 tonnes of Thanet sands

h. 1,110,000 tonnes of Chalk.

[iii] A diaphragm wall is a reinforced concrete retaining wall constructed in-situ. A deep trench is excavated and supported with bentonite slurry, and then reinforcing steel is inserted into the trench. Concrete is poured into the trench and only after this can excavation in front of the retained earth commence.

1.6.3 In addition, it is estimated that approximately 50,000 tonnes of general construction waste would be generated in total across the sites including wastage of 16,000 tonnes of imported fill and 25,000 tonnes of concrete. A total of approximately 450 tonnes per annum of welfare waste is estimated at all sites across the project.

1.6.4 The management, storage and transport of the excavated materials and wastes which arise at each site would form an integral part of the construction phase at each of the Thames Tideway Tunnel sites. The on-site and near-site environmental effects of this material are therefore captured within the consideration of construction effects for each topic within each site volume (see Vols 4 to 27). Where relevant, this also includes consideration of the environmental effects of transporting the material to the Transport for London Route Network (TLRN). The effects arising from the transportation of these materials to possible receptor sites are considered below.

Excavated material and waste strategy

1.6.5 The *Excavated materials and waste strategy (EM&W strategy)* (see Vol 3 Appendix A.3) has been developed to provide a framework for the management of excavated materials and waste that would be produced throughout the construction and operational phases of the Thames Tideway Tunnel project.

1.6.6 The *EM&W strategy* presents:

a. an outline of the measures that will deliver an effective system for the management of excavated material and waste from the project.

b. the detailed strategy that:

   i develops the approach for the control and sustainable management of excavated materials and waste that would be produced throughout the construction and operational phases of the project (see summary estimates in para. 1.6.2)

   ii sets out how the approach meets the requirements of the NPS to implement sustainable waste management through the application of the waste hierarchy

   iii demonstrates that the management of the excavated material and waste would not have an adverse effect on the capacity of existing waste management facilities to deal with other waste arisings in the area.

1.6.7 The *EM&W strategy* also provides further details on the use of a *Project-wide Waste Management Plan (Project-wide WMP)* and *Site Waste Management Plans (SWMP)*.

Excavated materials options assessment

1.6.8 The *Excavated materials options assessment (EMOA),* (Vol 3 Appendix A.4) uses a bespoke approach, developed in consultation with the Environment Agency (EA) that assesses the suitability of receptor sites that could receive excavated material from the Thames Tideway Tunnel project. The *EMOA* identifies a series of sites which achieve an appropriate level of sustainability performance (‘planning stage preferred list’) and also considers the available capacity at these sites.

1.6.9 Fourteen sites have been identified on the ’planning stage preferred list’ as follows:

a. Bournewood Inert Landfill Site
b. Barrington Landfill
c. RSPB - Wallasea Island (Wallasea Wetland Creation Project)
d. Summerleaze - Denham Quarry
e. Veolia Essex - Rainham Landfill
f. Calvert Landfill
g. Sutton Courtenay
h. Borough Green Quarry
i. Kingsmead Quarry
j. Little Belhus Landfill
k. Shipton on Cherwell Quarry
l. East Burnham Quarry
m. Tyttenhanger Quarry
n. Cliffe Pools.

1.6.10 The receptor sites on the planning stage preferred list and the reserve list (receptor sites with the potential to become available in the future) have a combined capacity of 77million tonnes. The estimated 4.7 million tonnes of excavated materials associated with the construction of the project would represent approximately 6.1% of the available capacity. This capacity assessment demonstrates that there is currently more than sufficient capacity to manage the excavated material anticipated from the project in a sustainable manner.

1.6.11 The Thames Tideway Tunnel project has a construction programme of more than six years with construction anticipated to start in 2016. Although the sites listed in para. 1.6.9 are currently believed to be viable during this period, it is not possible to guarantee that this will still be the case by the start of construction. In addition, it is highly likely that additional suitable sites would become available by the time construction starts as new opportunities for the beneficial use of uncontaminated bulk materials arise relatively frequently in South East England.

1.6.12 To enable contractors to utilise future suitable opportunities that arise, but at the same time provide reassurance to stakeholders in relation to beneficial re-use, a commitment is included within the *EM&W strategy* (see Vol 3 Appendix L.3). This commitment states that only receptor sites that meet or exceed the performance of the sites on the planning stage preferred list would be used for the receipt and management of excavated material.

1.6.13 Each site on the planning stage preferred list has consent for the relevant volumes of materials and any future sites which are considered would also have an appropriate consent. Given this, the environmental effects of waste at and near to the receptor sites (assumed to include HGV movements to / from the TLRN) would have already been considered within the relevant consenting processes. This *Environmental Statement* does not reassess these consented operations.

Assessment of the transport of materials and waste

1.6.14 This section briefly describes the requirements of the *Transport Strategy* that accompanies the application, in relation to the export of excavated materials and import and export of cofferdam fill, since these are used as assumptions for the assessment of project-wide transport effects. It also explains how the environmental effects of the use of the TLRN and / or barging (‘wharf to wharf’) have been considered in the EIA.

1.6.15 The delivery of construction materials and the export of excavated materials and wastes would be undertaken through a combination of road and river transport. Although there is no direct rail access to the sites, rail transport is likely to be part of a materials delivery route particularly for the constituent materials for ready mix concrete.

1.6.16 The *Transport Strategy*, that accompanies the application, proposes the following movements by river:

a. main tunnel excavated material from the main tunnel drive sites (ie, Carnwath Road Riverside, Kirtling Street, and Chambers Wharf)

b. import and export of cofferdam fill material at all foreshore sites

c. main tunnel shaft excavated material at Carnwath Road Riverside and King Edward Memorial Park Foreshore sites

d. shaft excavated material at ten sites in the foreshore or with direct river access (ie, Putney Embankment Foreshore, Carnwath Road Riverside, Cremorne Wharf Depot, Chelsea Embankment Foreshore, Heathwall Pumping Station, Albert Embankment Foreshore, Victoria Embankment Foreshore, Blackfriars Bridge Foreshore, Chambers Wharf and King Edward Memorial Park Foreshore)

e. excavated material for connection tunnels, interception works and associated structures at eight sites, namely Putney Embankment Foreshore, Cremorne Wharf Depot, Chelsea Embankment Foreshore, Albert Embankment Foreshore, Victoria Embankment Foreshore, Blackfriars Bridge Foreshore, Chambers Wharf and King Edward Memorial Park Foreshore

f. import of sand and aggregates for main tunnel secondary lining for main tunnel sites (ie, Carnwath Road Riverside, Kirtling Street and Chambers Wharf).

1.6.17 Whilst it would be preferable to move all of the above materials by river, for the transport assessment it has been assumed that a minimum of 90% of these materials would be transported by river. This is to allow some flexibility for the use of road transport for those periods where river transport may be unavailable and/or for material that is unsuitable for river transport, such as excessively wet spoil or any contaminated materials. The intention is to incentivise the construction contractors to move as much of the above material by river as practical in order to move closer to 100% of materials by river.

1.6.18 There will be certain materials that would require transport by road including materials excavated prior to the construction of river facilities, such as demolition, some shaft excavation material and smaller quantities of material that may require segregation for practicality or contamination reasons. Road transport would also be required if the use of the river was prevented for any period eg, due to extreme weather conditions or police/security incidents.

1.6.19 As noted in para. 1.6.4, the environmental effects of the transportation of these materials between project sites and the TLRN (or the loading into a barge) have been considered within the site assessments (see Vols 4 to 27). In addition, the transportation of these materials between the TLRN (or unloading of a barge) would have been considered within the consenting process for the receptor sites (see para. 1.6.13). The environmental effects of the use of the TLRN and / or barging ('wharf to wharf') are not captured within either of these assessments. However, an assessment of the carbon footprint of the logistics strategy presented within the *Transport Strategy* has been undertaken; and it is summarised in Vol 3 Appendix A.2 and presented in detail in the *Energy and Carbon Footprint Report*. Overall it is envisaged that there is a saving of approximately 7,000t CO_2e arising from the use of river transport over road transport.

Operational wastes

1.6.20 During the operational phase, the increased volumes of sewage captured within the main tunnel would lead to a corresponding increase in the solid waste arisings at the Beckton Sewage Treatment Works. This additional waste from the Thames Tideway Tunnel project would be inseparable from the existing solid waste stream and so would be dealt with in accordance wi*th Thames Water's* existing (and future) waste management procedures for sewage wastes.

This page is intention*ally blank*

Thames Tideway Tunnel
Thames Water Utilities Limited

Application for Development Consent

Application Reference Number: WWO10001

Environmental Statement

Doc Ref: **6.2.03**

Volume 3: Project-wide effects assessment

Section 2: Project context

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

Hard copy available in

Box **17** Folder **A**
January 2013

Thames Tideway Tunnel
Creating a cleaner, healthier River Thames

This page is intentionally blank

2 Project context

2.1 Introduction

2.1.1 This section provides an overview of the administrative and geographical context within which the project would be located, and the general environmental conditions present across the Thames Tideway Tunnel project's route. Detailed baseline conditions relevant to each topic assessment are described in Sections 4 to 15 of this volume.

2.1.2 The main tunnel would run for approximately 25km from the existing Thames Water's operational site at Acton Storm Tanks in west London to Abbey Mills Pumping Station in east London, across the administrative areas of 14 London local authorities including:

a. London Borough of Ealing

b. London Borough of Hammersmith and Fulham

c. London Borough of Hounslow

d. London Borough of Richmond upon Thames

e. London Borough of Wandsworth

f. Royal Borough of Kensington and Chelsea

g. London Borough of Lambeth

h. City of Westminster

i. City of London

j. London Borough of Southwark

k. London Borough of Tower Hamlets

l. London Borough of Lewisham

m. Royal Borough of Greenwich

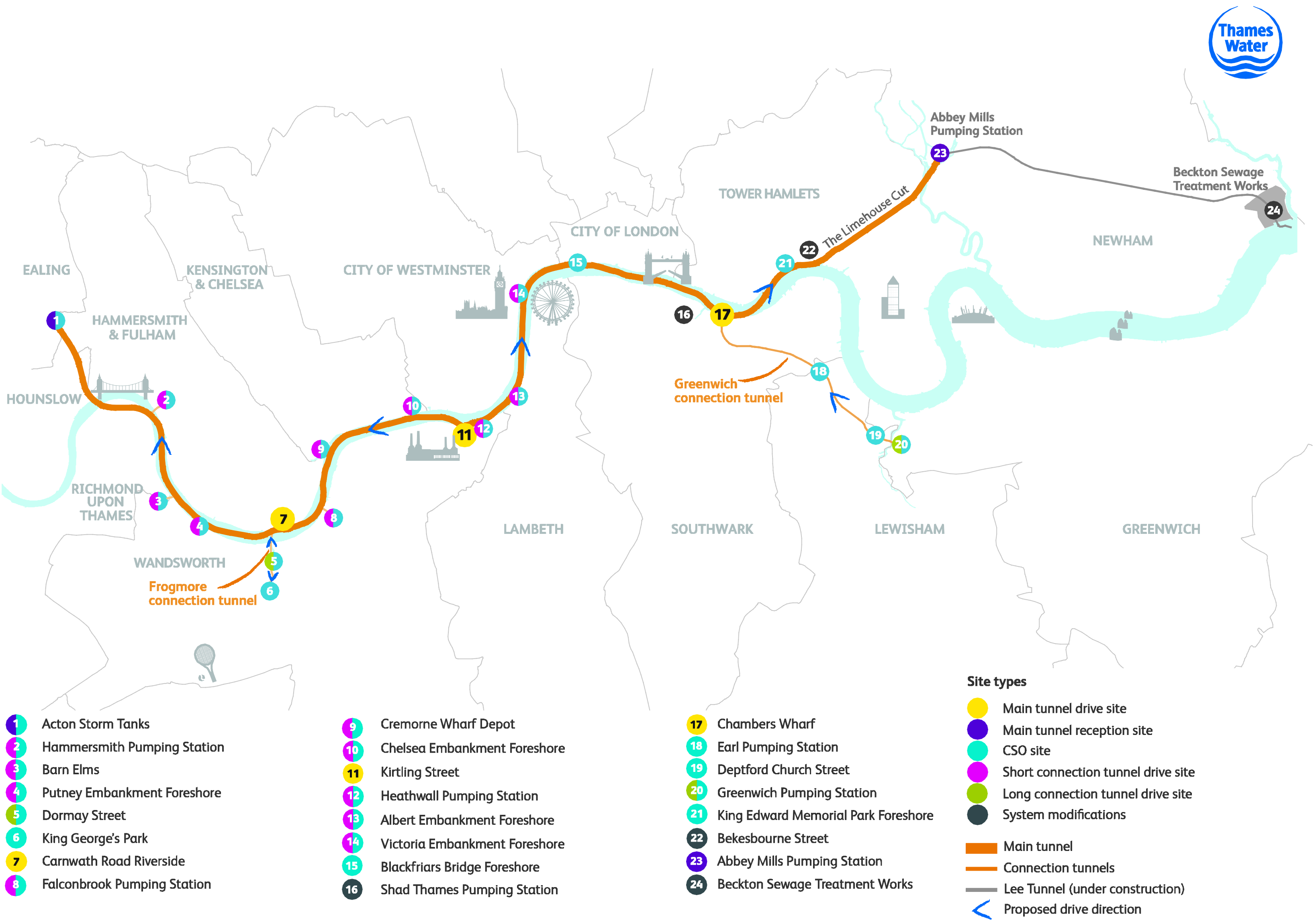
n. London Borough of Newham

2.1.3 London is the UK's capital city and the country's commercial and financial centre. The resident population of Greater London was estimated at 7,172,091 at the time of the last census for which data is available. The *London Plan 2011* predicts that London's population will increase by over one million people between 2011 and 2031, while employment in the capital is predicted to grow by 630,000 jobs.

2.1.4 London has one of the densest public transport networks of any city in the world comprising the London Underground, the Docklands Light Railway (DLR) and the London Overground, as well as buses and taxis services. National Rail services provide links to suburban locations and beyond. In addition, the River Thames is also used by passenger services, freight operators, leisure users and marine emergency services.

2.1.5 The project context and location is shown in Vol 3 Plate 2.1.1.

Vol 3 Plate 2.1.1 Schematic of the Thames Tideway Tunnel Project



2.2 Land uses along the route of main and connection tunnels

Acton Storm Tanks to Carnwath Road Riverside

2.2.1 From Acton Storm Tanks in the western end of the tunnel system, the main tunnel would run south across a developed urban area. The alignment would run under gardens or along roads to avoid passing under buildings where possible.

2.2.2 The tunnel would cross the above-ground District line and Piccadilly line railway near Stamford Brook Station and then continue south until it reaches the river.

2.2.3 The main tunnel would then cross beneath the River Thames and once on the southern bank of the river, the it would turn eastwards, passing south of Hammersmith Bridge and underneath a residential area, before passing back under the River Thames.

2.2.4 From here to Carnwath Road Riverside the main tunnel would run entirely under the River Thames, joining along the way to the connection tunnels from Hammersmith Pumping Station, Barn Elms, Putney Bridge Foreshore, Dormay Street and King's George Park.

2.2.5 The Hammersmith connection tunnel would join the Hammersmith Pumping Station drop shaft (east bank of the river) to the main tunnel under the river, approximately 250m east of the Hammersmith Bridge abutment. The connection tunnel would pass through a new development that is proposed on the east bank of the river.

2.2.6 The West Putney connection tunnel would join the drop shaft at Barn Elms, on the south side of the Beverly Brook gas main, to the main tunnel under the river.

2.2.7 The Putney Bridge connection tunnel would join the Putney Embankment Foreshore drop shaft, located in the south bank of the river, with the main tunnel under the river.

2.2.8 The main tunnel would then pass underneath Putney Bridge and Putney Rail Bridge, before connecting to the Carnwath Road Riverside main tunnel shaft on the northern bank of the river.

Frogmore connection tunnel

2.2.9 The Frogmore connection tunnel would be approximately 1,100m long and connect the drop shaft at King George's Park to the main tunnel at Carnwath Road Riverside via the online drop shaft at the Dormay Street site. Along the way the tunnel would pass through a built-up area with a number of existing tunnels in close proximity.

2.2.10 After the drop shaft at Dormay Street, the connection tunnel alignment continues north following the line of Bell Lane into the River Thames and under the viaduct. The connection tunnel would join the main tunnel at Carnwath Road Riverside main tunnel shaft after crossing the River Thames.

2.2.11 Vol 3 Plate 2.2.1 shows the proposed route between Acton Storm Tanks and Carnwath Road Riverside.

Vol 3 Plate 2.2.1 Route between Acton Storm Tanks and Carnwath Road Riverside

Map Ref: 1PL03-MG-00773

Carnwath Road Riverside to Kirtling Street

2.2.12 From Carnwath Road Riverside the main tunnel would generally follow the river to Kirtling Street.

2.2.13 East of Carnwath Road Riverside the main tunnel would pass under an industrial estate and underneath Wandsworth Bridge. After crossing beneath Wandsworth Bridge, the main tunnel would turn towards the eastern bank of the river to join the Falconbrook connection tunnel coming from Falconbrook Pumping Station.

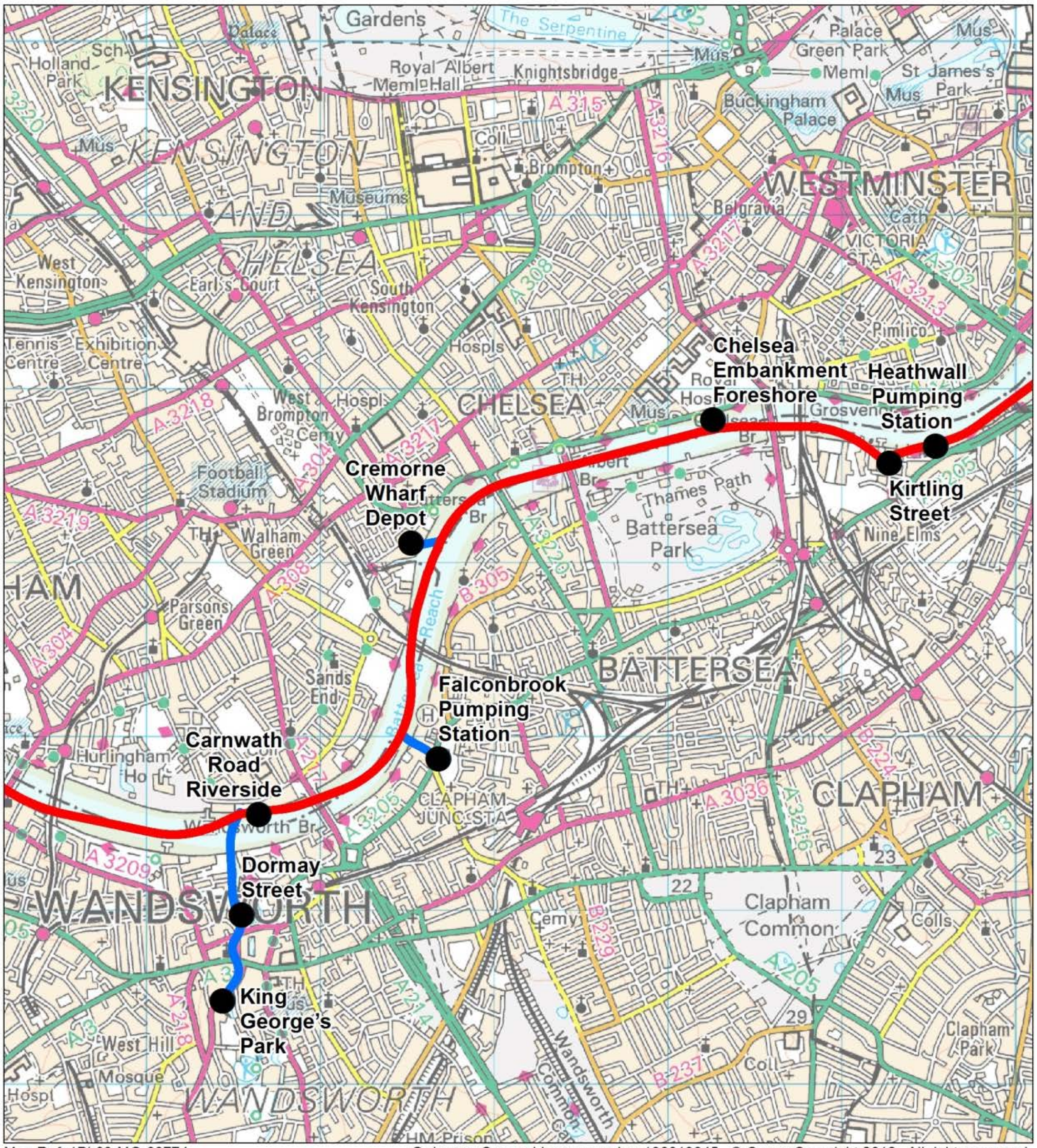
2.2.14 From here the main tunnel would head north passing below Battersea Rail Bridge before moving closer to the west bank of the river to connect to the Lots Road connection tunnel coming from Cremorne Wharf Depot.

2.2.15 The main tunnel would then follow the Chelsea Reach of the River Thames, passing under Battersea Bridge and Albert Bridge before joining the Ranelagh connection tunnel coming from Chelsea Embankment Foreshore.

2.2.16 The main tunnel alignment would next cross under Chelsea Bridge and Grosvenor Rail Bridge, before turning towards Kirtling Street on the south side of the river.

2.2.17 Vol 3 Plate 2.2.2 shows the proposed route between Carnwath Road Riverside and Kirtling Street.

Vol 3 Plate 2.2.2 Route between Carnwath Road Riverside and Kirtling Street



Map Ref: 1PL03-MG-00774

Kirtling Street to Chambers Wharf

2.2.18 As the main tunnel heads east from Kirtling Street it would remain north of the residential development currently under construction and pass under the jetty adjacent to the Tideway Industrial Estate, before joining the Heathwall/SWSR connection tunnel coming from Heathwall Pumping Station.

2.2.19 The main tunnel would continue to the south of the river centreline, passing below Vauxhall Bridge before joining the Clapham/Brixton connection tunnel from Albert Embankment Foreshore site under the river.

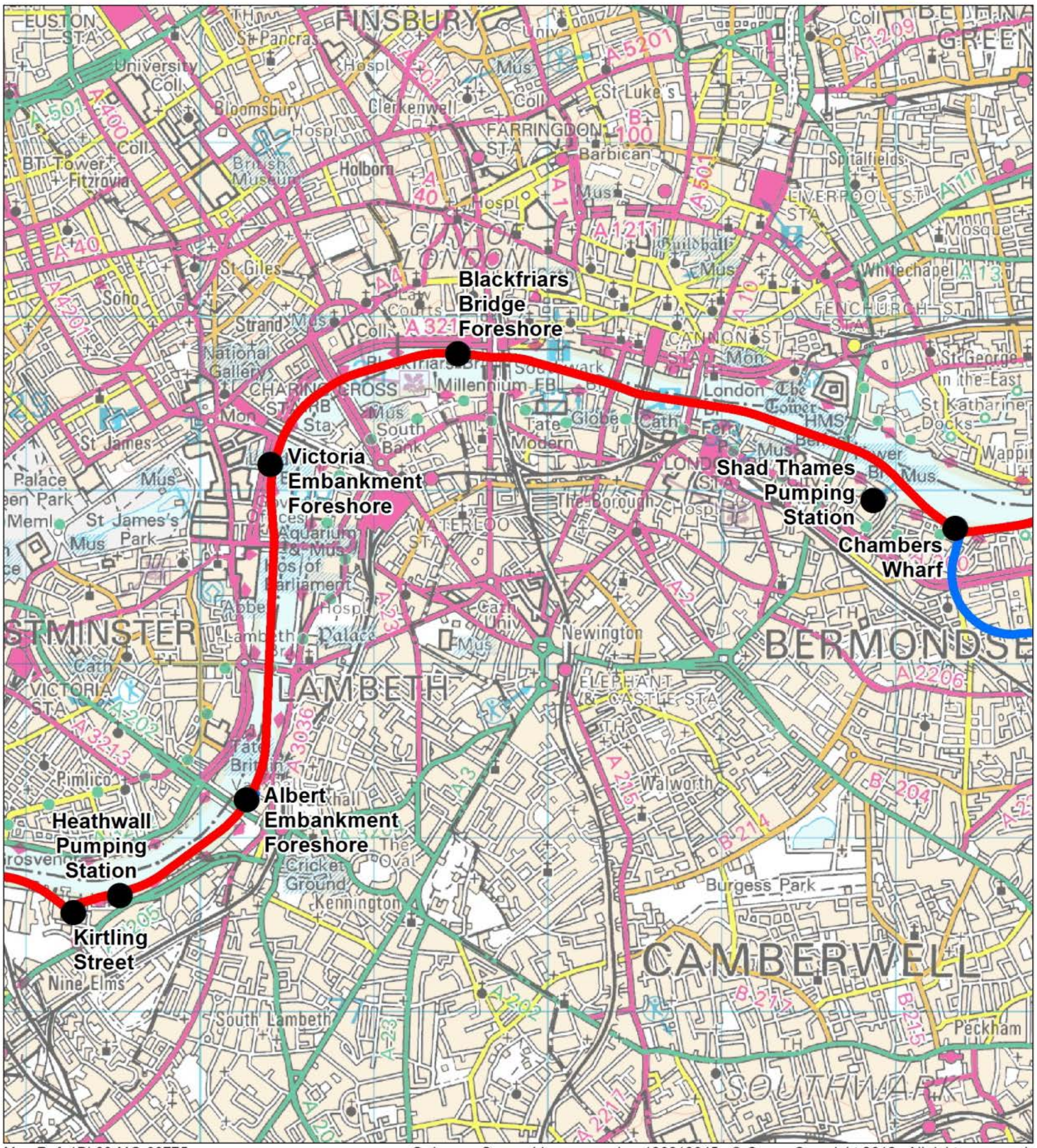
2.2.20 From here the main tunnel would head northwards, crossing underneath Lambeth Bridge, Westminster Bridge and the Jubilee Line tunnels, before joining the Regent Street connection tunnel coming from Victoria Embankment Foreshore site under the river.

2.2.21 After the Regent Street connection tunnel, the main tunnel would pass below, Hungerford Bridge. It would then continue on the north side of the river centreline towards Blackfriars Bridge Foreshore, passing under Waterloo Bridge along the way. From the Blackfriars Bridge Foreshore drop shaft (on-line) the main tunnel would continue close to the northern bank of the river, passing below Blackfriars Bridge and Blackfriars Rail Bridge. From the east of the Blackfriars bridges, the tunnel would then follow the middle of the river as far as possible, passing below Millennium Bridge, Southwark Bridge, Cannon Street Bridge, London Bridge and Tower Bridge.

2.2.22 After crossing Tower Bridge, the alignment moves across to the southern side of the river in front of St Saviour's Dock to join the main tunnel shaft at Chambers Wharf.

2.2.23 Vol 3 Plate 2.2.3 shows the proposed route between Kirtling Street and Chambers Wharf.

Vol 3 Plate 2.2.3 Route between Kirtling Street and Chambers Wharf



Map Ref: 1PL03-MG-00775

Greenwich connection tunnel

2.2.24 The Greenwich connection tunnel would be approximately 4,600m long and link the drop shafts at the Greenwich Pumping Station, Deptford Church Street and Earl Pumping Station sites and connect them to the main tunnel shaft in Chambers Wharf. Along its route it would pass through a dense urban area, including residential properties, open space (eg, Southward Park) and industrial units.

2.2.25 It would also pass under the operational Jubilee Line tunnels, the East London Overground Line, the rail viaduct for the main line trains to London Bridge, close to the lifting bridge on Deptford Creek and under the precast Docklands Light Railway (DLR) viaduct before reaching Greenwich Pumping Station.

2.2.26 Vol 3 Plate 2.2.4 shows the route of the Greenwich connection tunnels.

Vol 3 Plate 2.2.4 Greenwich connection tunnel route

Map Ref: 1PL03-MG-00776

Chambers Wharf to Abbey Mills Pumping Station

2.2.27 From Chambers Wharf (south bank of the river) the main tunnel would continue north under the River Thames, passing beneath the Rotherhithe tunnel before reaching King Edward Memorial Park Foreshore site in the northern bank of the river.

2.2.28 From the King Edward Memorial Park Foreshore the main tunnel would continue eastwards towards the entrance to the Limehouse Basin. The alignment would turn northward to pass under the Old Sun Wharf as it cuts across towards the east side of the basin.

2.2.29 North of the basin the main tunnel would avoid passing directly beneath the high-rise buildings on Wharf Lane and Commercial Road. It would then follow the Limehouse Cut towards Abbey Mills Pumping Station.

2.2.30 Following the Limehouse Cut as far as the Blackwall Tunnel Northern Approach Road, the main tunnel would pass under the low rise buildings at Barratt Industrial Park as it turns to a more northerly direction across the River Lee. Keeping to the west of the gas holders, the main tunnel would cross under the surface rail tracks of the District Line and across the Channelsea River, passing into the Abbey Mills Pumping Station land where the main tunnel shaft is located.

Vol 3 Plate 2.2.5 Route from Chambers Wharf to Abbey Mills Pumping Station

Map Ref: 1PL03-MG-00777

2.3 Environmental conditions

2.3.1 Environmental designations along the project route are shown in Vol 3 Figure 2.3.1 to Vol 3 Figure 2.3.4 (see separate volume of figures).

2.3.2 London's air quality has improved dramatically since the 1950s when legislation was introduced to prevent the smogs that were a common occurrence in the capital. Despite this, air pollution is still an issue in London affecting health and everyday quality of life, in particular for those parts of the city where EU targets for the most harmful pollutants nitrogen dioxide (NO_2) and fine particulate matter (PM_{10}) are not being met (Mayor of London, 2010)[10]. As a result most London local authorities have designated Air Quality Management Areas (AQMAs) for those places where the targets are not likely to be achieved.

2.3.3 The tidal Thames is part of the proposed South East Marine Conservation Zone (MCZ) designated for the range of nationally biodiversity it supports, including important spawning habitat for smelt.

2.3.4 There are a number of statutory and non-statutory sites for nature conservation along the River Thames, including:

a. Thames Estuary and Marshes Special Protection Area (SPA)

b. Inner Thames Marshes, Syon Park and Barn Elms Wetland Centre Sites of Special Scientific Interest (SSSIs)

c. Dukes Hollow, Leg of Mutton Reservoir, Aisleworth Ait/Ayot, Chiswick Ayot and Lavender Pond Local Nature Reserves (LNRs)

d. River Thames and Tidal Tributaries (Grade III Metropolitan importance) (also part of the South East MCZ) and Beverley Brook Sites of Importance for Nature Conservation (SINCs).

2.3.5 The River Thames supports a diverse mix of habitats including gravel foreshore, mudflat, sublitoral sands and gravels[11]. Gravel foreshore refers to the intertidal substrate comprising gravel and sands. Mudflats refer to the intertidal substrate comprising mud and sands which are a rich source of invertebrates (shellfish, worms and crustaceans) and provide feeding grounds for large numbers of wintering waterfowl. Sublittoral sands and gravels are found below the lowest tides, continuously submerged loose sediment. They represent an important habitat for invertebrates and provide spawning substrate for fish eg, smelt.

2.3.6 Generally habitats are more diverse upstream of Chelsea, with large gravel foreshores below the river walls, which are exposed at low tide in sites between Hammersmith and Wandsworth. Many of these upstream sites ie, Hammersmith Pumping Station, Barn Elms and Putney Embankment Foreshore have trees and other marginal vegetation on and above the river wall. Throughout central London, the River Thames is more constrained within the river walls, and the intertidal habitat is narrower and consists of homogeneous sand and gravel. The vertical river wall made of timber, brick and concrete can also support a wide diversity of plants and invertebrates.

2.3.7 There are a number of tributaries and tidal creeks which discharge into the River Thames, including Bell Lane Creek, Chelsea Creek, Deptford Creek and the River Lea (and its tributaries). These are also known to be important areas for fish.

2.3.8 The above habitats support a wide range of species, including wintering birds, fish and invertebrates. Some rare and notable fish species of conservation concern (ie, sea and river lamprey, atlantic salmon and

European eel), migrate through the Thames Estuary and the tidal Thames to reach freshwater habitats.

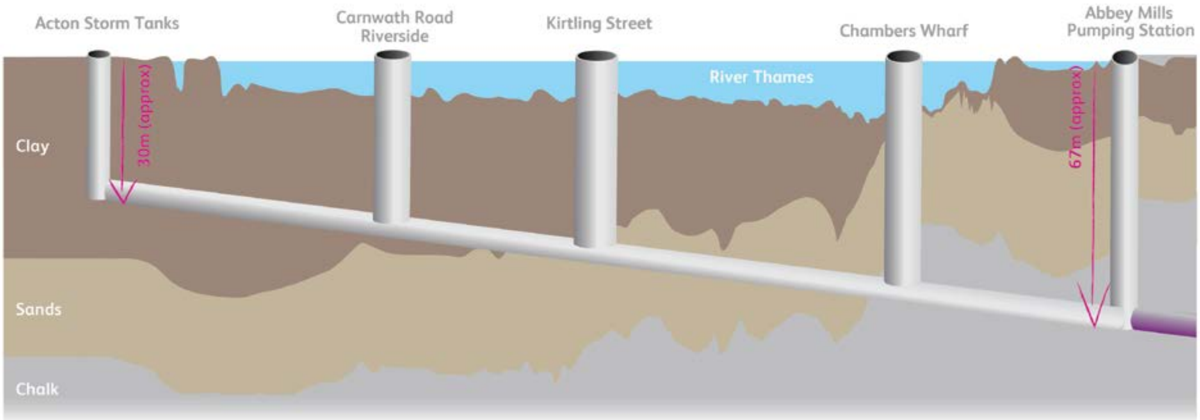
2.3.9 The River Thames is also visited from time to time by several species of marine mammals such as dolphins, porpoises and seals.

2.3.10 There are a number of nationally designated heritage assets along the project route, including schedule monuments, listed buildings and structures such as Tower Bridge (Grade I listed structure) and river walls. The project falls within the boundaries of thirteen Conservation Areas and eighteen Archaeological Priority Areas (APAs).

2.3.11 The geology and hydrogeology varies across the route of the main tunnel and long connection tunnels. The tunnels would pass from west to east through a sequence of sedimentary strata. In the west between Acton Storm Tanks and Chelsea Embankment Foreshore, the main tunnel would be principally in London Clay. In the central area between Chelsea Embankment Foreshore and Chambers Wharf, the main tunnel would be in the Lambeth group comprising mixed material of gravels, sand and clay and Thanet Sand Formation. At the eastern end, between Chambers Wharf and Abbey Mills Pumping Station, the main tunnel would be in Chalk. The Frogmore connection tunnel in the west would be entirely within London Clay; whilst the Greenwich connection tunnel in the east would be entirely within the Chalk.

2.3.12 Vol 3 Plate 2.3.1 shows a schematic of the geological sequence along the project's route.

Vol 3 Plate 2.3.1 Schematic geological sequence along Thames Tideway Tunnel project route



2.3.13 The Chalk is the major aquifer of the London Basin and is confined over much of the area by the Palaeogene strata (comprising the London Clay Formation, the Lambeth Group and Thanet Sand Formation), superficial deposits (Alluvium and River Terrace Deposits) and Made Ground. The River Terrace Deposits are considered a minor aquifer consistent of permeable layers capable of supporting water supplies at a local scale, The Chalk and the River Terrace Deposits aquifers are generally hydraulically separated by the London Clay Formation within the west and central sections of the main tunnel alignment.

2.3.14 The proposed main tunnel alignment along the course of the River Thames, as well as the requirement to intercept CSO and the commitment to use a high proportion of river transport for export of excavated materials, requires that most Thames Tideway Tunnel sites are located close to the foreshore. Therefore most of the sites would fall within Flood Zones 3a and 3b and are categorised as being at high risk of flooding by the Environment Agency. This flood risk typically follows the River Thames corridor, varying in areas due to local topography, flood protection measures and confluences of tributaries into the River Thames.

Thames Tideway Tunnel
Thames Water Utilities Limited

Application for Development Consent

Application Reference Number: WWO10001

Environmental Statement

Doc Ref: **6.2.03**

Volume 3: Project-wide effects assessment

Section 3: Proposed development

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

Hard copy available in

Box **17** Folder **A**
January 2013

Thames Tideway Tunnel
Creating a cleaner, healthier River Thames

This page is intentionally blank

3 Proposed development

3.1 Overview

3.1.1 The Thames Tideway Tunnel project comprises a combined sewage storage and transfer tunnel ('the main tunnel') between Thames Water's existing operational sites at Acton Storm Tanks and Abbey Mills Pumping Station, which would intercept the CSOs that frequently discharge into the tidal Thames and capture the flows of combined sewage. The flows would be stored[iv] in the main tunnel system and transferred to Beckton Sewage Treatment Works for treatment via a connection to the Lee Tunnel at Abbey Mills Pumping Station.

3.1.2 During and following storm events, when the sewers are unable to accommodate 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.

3.1.3 The main components of the Thames Tideway Tunnel project are:

a. tunnels: the main tunnel and connection tunnels that link CSOs to the main tunnel. There are two types of connection tunnels:

   i long connection tunnels which connect with the main tunnel via a shaft; these are known as Frogmore connection tunnel and Greenwich connection tunnel

   ii short connection tunnels which connect directly with the main tunnel.

b. sites: 24 sites would be required for the construction and maintenance of the Thames Tideway Tunnel project as follows:

   i main tunnel shaft sites that are needed to construct the main tunnel

   ii CSO drop shaft and interception sites that are needed to construct the interception works and transfer the controlled flows to the tunnel system and associated connection tunnels

   iii system modification sites to undertake existing sewer system modifications to aid in control of CSO

   iv works at Beckton Sewage Treatment Works to receive flows from the tunnel system for treatment.

3.1.4 The geographic extent of the proposals for which development consent is sought is defined by the limits of deviation (LOD) for the main and connection tunnels, and the limits of land to be acquired or used (LLAU) for above-ground works at each project site. Work plans showing LOD and LLAU for the whole length of the project are included in a separate

[iv] It should be noted that wastewater would only be stored in the tunnel for a temporary period until it can be pumped out at Beckton Sewage Treatment Works.

volume of figures (see Vol 3 Project-wide effects assessment figures - Section 1).

3.1.5 The elements of the proposed development relevant to the assessment of project-wide effects vary between topics and depend on the scope of the project-wide assessments. For some topics the assessment relates mainly to elements at several project sites eg, aquatic ecology, whilst for others it relates mainly to the main tunnel itself eg, groundwater.

3.1.6 A summary description of the project is provided in Vol 1 Section 2, including an overview of the main and connection tunnels as well as the proposed works at each project site. Detailed description of the proposed development at each of the project sites is provided in Section 3 of Vols 4 to 27 and has therefore not been replicated within this volume. Short connection tunnels, which are associated with specific sites, are described in detailed in these sections.

3.1.7 The following Sections 3.2, 3.3 and 3.4 focus on those elements of the project that are not necessarily associated with a particular site but which would cover a wider geographical area (ie, main and long connection tunnels) and thus are not covered within the detailed description of the proposed development provided in the site assessments (see Vols 4 to 27).

3.1.8 Section 3.2 describes those elements of the main and long connection tunnels for which development consent is sought. In Section 3.3, assumptions are presented on how the main and long connection tunnels are likely to be constructed and include the assumed programme and typical construction activities associated with these elements of the project. Section 3.4 sets out the operational assumptions in terms of these operational structures and their typical maintenance regime. These construction and operational assumptions underpin the assessment.

3.1.9 Other development may become operational in advance of or during the Thames Tideway Tunnel project thereby changing the baseline conditions. In order to undertake an accurate assessment it is necessary to compare the predicted situation with the Thames Tideway Tunnel project in place with this future baseline conditions ('base case') (rather than comparing it with the current conditions). In addition, other development may be under construction at the same time as construction or operation of the Thames Tideway Tunnel project and this could lead to cumulative effects. Information regarding the schemes included in the base case and in the project-wide cumulative assessment is summarised in Section 3.5 with details included in Vol 3 Appendix A.1. The methodology for identifying these schemes is explained in Vol 2 Sections 3.4 and 3.8.

3.2 Defined project: main and long connection tunnels

3.2.1 This section identifies only those elements of the proposed development associated with the main and long connection tunnels, for which consent is sought. Vols 4 to 27 provide a detailed definition of those elements of the proposed development associated with the individual sites eg, main tunnel/CSO drop shafts, short connection tunnels etc.

3.2.2 Vol 3 Table 3.2.1 below identifies where those elements of the main and long connection tunnels for which consent is sought and which have been assessed, are described in the application.

Vol 3 Table 3.2.1 Plans and documents defining the main and long connection tunnels

Document / plan title	Status	Location
Proposed schedule of works	For approval	Schedule 1 *of the Draft Thames Water Utilities Limited (Thames Tideway Tunnel) Development Consent Order 201[ ] (Draft DCO)* (see relevant extracts in para. 3.2.6)
Limits of deviation	For approval	Part 2 of the *Draft DCO* (see paras. 3.2.9 to 3.2.11)
Works plans and sections	For approval	Vol 3 Project-wide effects assessment figures - Section 1
Code of Construction Practice Part A (CoCP) Part A: General Requirements	For approval	*CoCP* Part A (see Vol 1 Appendix A)
Code of Construction Practice (CoCP) Part B: Site Specific Requirements (some of which would be relevant to the main and long connection tunnels eg, working hours)	For approval	*CoCP* Part B (see Vol 1 Appendix A)

Description of the proposed works

3.2.3 Schedule 1 of the *Draft DCO* provides a description of works for which development consent is sought. The schedule describes the main tunnel, connection tunnels and also the works which would be required at each of the proposed sites within the project. This includes the works comprising the nationally significant infrastructure (NSIP) and associated development (which are described in Part 1 of Schedule 1) and ancillary works (which are described in Part 2 of Schedule 1).

3.2.4 The following sections provide a description of the proposed works associated with the main and long connection tunnels under the following headings: Nationally significant infrastructure project, Associated development and Ancillary works. The description of the proposed works has been taken from Schedule 1 to the *Draft DCO* and the codes given for the works are those given within that schedule.

3.2.5 In accordance with the *Draft DCO*, all distances, directions and lengths referred to are approximate. All distances for scheduled linear works referred to are measured along the centre line of the limit of deviation for that work. Internal diameters for tunnels are the approximate internal dimensions after the construction of a tunnel lining. Unless otherwise stated, depths are specified to invert level and are measured from the proposed final ground level.

Nationally significant infrastructure project

3.2.6 The proposed structures and works required in relation to the main and long connection tunnels which comprise the nationally significant infrastructure project are described below. Nationally significant infrastructure project works associated with each particular site eg, main tunnel and CSO drop shafts, short connection tunnels etc, are presented in Section 3 of Vols 4 to 27.

Main tunnel

a. **Work No.1a:** Main tunnel (west): A tunnel with an internal diameter of 6.5 metres and 6950 metres in length between Acton Storm Tanks main tunnel shaft (Work No. 2a) and Carnwath Road Riverside main tunnel shaft (Work No. 6a).

b. **Work No.1b**: Main tunnel (west central): A tunnel with an internal diameter of 7.2 metres and 5000 metres in length between Carnwath Road Riverside main tunnel shaft (Work No. 6a) and Kirtling Street main tunnel shaft (Work No. 13a).

c. **Work No. 1c:** Main tunnel (east central): A tunnel with an internal diameter of 7.2 metres and 7670 metres in length between Kirtling Street main tunnel shaft (Work No. 13a) and Chambers Wharf main tunnel shaft (Work No. 19a).

d. **Work No. 1d:** Main tunnel (east): A tunnel with an internal diameter of 7.2 metres and 5520 metres in length between Chambers Wharf main tunnel shaft (Work No. 19a) and Abbey Mills Pumping Station main tunnel shaft (Work No. 26a)

Frogmore connection tunnel

a. **Work No. 7**: Frogmore connection tunnel **-** A tunnel with an internal diameter of 2.6 to 3 metres and 1120 metres in length between Carnwath Road Riverside main tunnel shaft (Work No. 6a) and King George’s Park drop shaft (Work No. 9a)

Greenwich connection tunnel

a. **Work No. 20**: Greenwich connection tunnel – A tunnel with an internal diameter of 5.0 metres and 4610 metres in length between Chambers Wharf main tunnel site (Work No. 19a) and Greenwich Pumping Station drop shaft (Work No. 23a).

Associated development and Ancillary works

3.2.7 The proposed structures and works required at each specific site which comprise the associated development, within the meaning of section 115(2) of the Planning Act 2008 (eg, works to intercept and divert flows from existing CSOs), are described in Section 3 of Vols 4 to 27. Associated development also includes a number of other works in relation with the construction areas such as enclosures, demolition works, provision of welfare facilities and vehicle access etc. In addition, ancillary works which are not "development" as defined in section 32 of the Act, but do however form part of the Thames Tideway Tunnel project for which development consent is being sought, are also described in Section 3 of Vols 4 to 27 and within Schedule 1 of the *Draft DCO* which accompanies the application.

3.2.8 There is no associated development or ancillary works in relation to the main tunnel and long connection tunnels.

Limits of deviation

3.2.9 Limits of deviation (LOD) are applied to main and connection tunnels and are defined on the Works plans and section drawings (see separate volume of figures - Section 1).

3.2.10 In addition, Part 2 (works provisions) of the *Draft DCO* states that in constructing or maintaining the main and connection tunnels, the undertaker may deviate:

a. laterally from the lines, situations or positioning of the authorised development shown or indicated on the works plans to the extent of the limits of deviation shown on the works plans; and

b. vertically from the limits of the authorised development shown on the sections to any extent:

   i not exceeding 3 metres upwards; or

   ii downwards as may be found to be necessary or convenient.

3.2.11 The horizontal LOD for the main and long connection tunnels are given in Vol 3 Table 3.2.2.

Vol 3 Table 3.2.2 Horizontal limits of deviation

Tunnel	LOD (meters from tunnel centerline)
Main tunnel (7.2m internal diameter)	14.60
Main tunnel (6.5m internal diameter)	14.25
Frogmore connection tunnel (2.6m to 3.0m internal diameter)	20.00
Greenwich connection tunnel (5.0m internal diameter)	13.50

Design Principles

3.2.12 The design principles for the project have been developed with stakeholders and set out the parameters that must be met in the final detailed design of the above-ground structures and spaces associated with the project. The principles do not apply to below-ground structures eg, main and connection tunnels, and therefore are not discussed further within this section.

3.2.13 The *Design Principles* report (generic and site-specific) is provided in Vol 1 Appendix B. Site-specific principles are also discussed in further detailed within Vols 4 to 27 where they apply to specific sites.

Code of Construction Practice

3.2.14 All works would be undertaken in accordance with the *Code of Construction Practice (CoCP)*. The *CoCP* sets out a series of measures to protect the environment and limit disturbance from construction activities as far as reasonable practicable. These measures would be applied throughout the construction process, and would be the responsibility of the contractor to implement.

3.2.15 The *CoCP* is provided in Vol 1 Appendix A and comprises two parts, Part A and Part B. Part A presents measures which are applicable across the project and Part B defines measures which are only applicable at individual sites.

3.2.16 The *CoCP* forms an integral part of the project and all of the measures contained therein are assumed to be in place during the construction process described in Section 3.3 below. The measures are not described within Section 3.3 although further details on the measures within the *CoCP* are given within the relevant project-wide topic assessments (see Sections 4 to 15 of this volume).

3.3 Construction assumptions: main and long connection tunnels

3.3.1 This section describes the approach to construction which has been assumed for the purpose of the EIA in relation to the main tunnel and long connection tunnels. The working methods and the construction programme are illustrative and do not form part of the project for which consent is sought.

3.3.2 Although the construction programme and working methods described are illustrative, they represent what is considered to be the likely approach, given the design requirements, route constraints, anticipated ground conditions, above-ground land uses and the construction requirements. This section describes the main activities with the focus on those that are relevant for the assessment of environmental effects associated with the main and long connection tunnels.

3.3.3 The assumed construction programme is described first, followed by a description of typical construction activities.

3.3.4 It is also assumed that, where the appropriate powers do not form part of the Development Consent Order, further consents may be required before certain construction activities are progressed. These could include various consents issued by the Environment Agency (EA) (including flood defence consents, abstraction licenses and discharge consents) as appropriate.

Assumed construction programme and working hours

3.3.5 Construction of the Thames Tideway Tunnel project would be likely to commence in 2016 (Project Year 1) and would be completed by 2022 (Project Year 7). The main and long connection tunnels would be operational in 2023 when the Thames Tideway Tunnel project as a whole becomes operational.

3.3.6 Construction of the main and long connection tunnels would take place simultaneously at several sites over the project's construction programme as follows:

a. main tunnel from Carnwath Road Riverside to Acton Storm Tanks:
   - i tunnelling approximately 22 months (between 2016 and 2018) serviced from Carnwath Road Riverside
   - ii secondary lining approximately 7 months (between 2019 and 2020) , serviced from Carnwath Road Riverside and Acton Storm Tanks

b. main tunnel from Kirtling Street to Carnwath Road Riverside and from Kirtling Street to Chambers Wharf:
   - i tunnelling approximately 26 months (between 2016 and 2018)service from Kirtling Street
   - ii secondary lining approximately 7.5 months (between 2019 and 2020) serviced from Carnwath Road Riverside, Kitrling Street and Chambers Wharf

c. main tunnel from Chambers Wharf to Abbey Mills Pumping Station:
   - i tunnelling approximately 25 months (between 2016 and 2018) serviced from Chambers Wharf
   - ii secondary lining approximately 8 months (between 2019 and 2020) service from Chambers Wharf and Abbey Mills Pumping Station

d. Frogmore connection tunnel from Dormay Street to King George's Park and Carnwath Road Riverside:
   - i tunnelling approximately 9 months (during 2016) serviced from Dormay Street
   - ii secondary lining approximately 5.5 months (during 2018) serviced from Dormay Street

e. Greenwich connection tunnel between Greenwich Pumping Station and Chambers Wharf:
   - i tunnelling approximately 20 months (between 2016 and 2018) serviced from Greenwich Pumping Station

ii secondary lining approximately 8 months (between 2019 and 2020) serviced from Greenwich Pumping Station and Chambers Wharf.

3.3.7 It is assumed that continuous working hours (24 hours) would be required seven days a week for tunnelling and secondary lining works at the tunnels drive sites for the duration indicated above.

3.3.8 The above programme assumes that tunnelling would progress at the average advance rates shown in Vol 3 Table 3.3.1. Drives rates are based on 24 hour working and make allowance for the ground conditions and consequently the type of TBM used.

Vol 3 Table 3.3.1 Assumed main and long connection tunnels drive rates

Ground condition – TBM type	Average rate (m/week)
Main tunnel	
London Clay – EPB* TBM	100
Woolwich and Reading / Thanet Sands – EPB TBM	90
Chalk – EPB TBM	50
Chalk – Slurry TBM	80
Frogmore connection tunnel	
London Clay – EPB TBM	60
Greenwich connection tunnel	
Chalk – Slurry TBM	80

**Earth Pressure Balance (EPB)*

3.3.9 The tunnel secondary lining can only be started once the tunnel drive has been completed. Assumed secondary lining rates are 140m/week for the main tunnel and 100m/week for the long connection tunnels.

3.3.10 The *CoCP* (see Vol 1 Appendix A) provides further details on working hours for different construction activities.

Typical construction activities

3.3.11 The methods, order and timing of the construction work outlined herewith are illustrative, but representative of a practical method to construct the works and suitable upon which to base the assessment.

3.3.12 The following construction activities associated with the main and long connection tunnels are described:

a. tunnel construction

b. tunnel secondary lining

c. access and movement.

Tunnel construction

3.3.13 The main tunnel and two long connection tunnels would be constructed using tunnel boring machines (TBMs), including Earth Pressure Balance (EPB) and Slurry TBMs. Shafts would be constructed down to an appropriate depth at both ends of a tunnel. The TBM would start from a drive shaft and would tunnel to a reception shaft where it would be removed. A shaft may serve as both a drive shaft for one length of tunnel and a reception shaft for another length of tunnel.

3.3.14 The main tunnel drive sites would be major construction sites used to assemble and then drive the TBM, deal with the excavated material from driving the tunnel, store concrete (segments) for the primary lining of the main tunnel and deliver these to the TBM via the shaft. Construction plans have been prepared to illustrate possible site layouts for the principal construction phases, including surface activities associated with tunnelling. These plans are described in Section 3.3. of Vols 4 to 27.

3.3.15 As the tunnel is advanced, excavated material from the face of the TBM would be removed from the tunnel using either a conveyor, a construction railway or hydraulically using a pipeline. After completion of the excavation stage a precast concrete gasketted segmental rig would be erected to form the primary lining. The concrete tunnel primary lining consists of a set of concrete segments that are erected to form a complete ring and bolted to the lining segments previously assembled. The tunnel segments would be lowered into the shaft by a crane and delivered by a construction train on a temporary construction railway within the tunnel to the TBM. Grout would be injected behind the rings 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 tunnel lining. In stable, impermeable strata the TBM can mine through a pre-formed tunnel entrance in the shaft as there is no water pressure, nor unstable ground to support.

3.3.16 Where the TBM would mine through pressurised or unstable strata (Lambeth, Thanet Sands and Chalk), additional measures would be required as necessary to ensure the stability of the launch and reception works. These measures can include:

a. dewatering, de-pressurisation and ground improvement immediately adjacent to the shaft

b. sealed launch or reception chambers installed within the shaft to isolate external water pressures

c. fibreglass diaphragm wall reinforcement at tunnel level to assist the launch and reception of TBMs into the shafts.

3.3.17 Vol 3 Table 3.3.2 shows the direction of the tunnel drives, the assumed dimensions and construction methods and the anticipated ground type for the main and long connection tunnels.

Vol 3 Table 3.3.2 Main and long connection tunnels summary

From	To	Length (m)	Internal diameter (m)	Assumed construction method	Main ground type
Main tunnel					
Carnwath Road Riverside	Acton Storm Tanks	6,950	6.5	EPB TBM	London Clay
Kirtling Street	Carnwath Road Riverside	5,000	7.2	EPB TBM	London Clay, Lambeth Group
Kirtling Street	Chambers Wharf (via Blackfriars Bridge Foreshore)	7,670	7.2	EPB TBM	London Clay, Lambeth Group, Thanet Sands, Chalk
Chambers Wharf	Abbey Mills Pumping Station ((via King Edward Memorial Park Foreshore)	5,520	7.2	Slurry TBM	Chalk
	Total	25,140			
Frogmore connection tunnel					
Dormay Street	King George’s Park	510	2.6 to 3.0	EPB TBM / open shield	London Clay
Dormay Street	Carnwath Road Riverside	610	2.6 to 3.0	EPB TBM / open shield	London Clay
	Total	1,120			
Greenwich connection tunnel					
Greenwich Pumping Station	Chambers Wharf (via Deptford Church Street and Earl Pumping Station)	4,610	5.0	Slurry TBM	Chalk

Tunnel secondary lining

3.3.18 Secondary lining is an additional layer of concrete placed against the inside of the tunnel's primary concrete segmental lining required for watertightness and to improve the overall structural durability. For the purpose of the assessment, it has been assumed that both the main and connection tunnels would have reinforced concrete secondary lining.

3.3.19 It has been assumed that on completion of the tunnelling phase, concrete batching plants would be mobilised to the main tunnel drive and reception sites and at Greenwich Pumping Station to supply the secondary lining for the main tunnel and Greenwich connection tunnel. Concrete would be batched on surface and pumped or skipped to the tunnel. An underground railway would be used to transport the concrete and reinforcement to the area of the pour. Secondary lining for the Frogmore connection tunnel is expected to use ready mix concrete from local suppliers.

3.3.20 The secondary lining would be constructed by installing steel reinforcement, erecting a cylindrical shutter within a short length of tunnel and pumping concrete into the gap between the shutter and the primary lining. Once the concrete has hardened sufficiently, the shutters would be removed and erected in the next section of tunnel.

3.3.21 For the main tunnel the secondary lining works would be constructed from the main tunnel drive and reception shafts. For the Greenwich connection tunnel the lining would be constructed from both the Greenwich Pumping Station drop shaft and the Chambers Wharf main tunnel shaft. For the Frogmore connection tunnel the lining would be constructed from the Dormay Street drop shaft.

Access and movement

3.3.22 For the purpose of the assessment it has been assumed that 90% of the following materials would be transported by river, with the residual 10% transported by road, to account for periods where river transport is not available or the material is unsuitable for transport by barge:

a. main tunnel excavated material from main tunnel drive sites (ie, Carnwath Road Riverside, Kirtling Street and Chambers Wharf)

b. import sand and aggregates for main tunnel secondary lining for main tunnel sites at Carnwath Road Riverside, Kirtling Street and Chambers Wharf.

3.3.23 Excavated material from the Frogmore and Greenwich long connection tunnels would be transported by road.

3.3.24 All other materials as well as construction plant (including TBMs) would be delivered to the sites by road.

3.4 Operational assumptions: main and long connection tunnels

3.4.1 This section provides details of the assumptions which have been made for the operational phase in relation to the main and long connection tunnels for the purposes of the EIA. Operational assumptions with regards to other elements of the project eg, shafts, chambers, culverts etc are described in detailed within Section 3 of Vols 4 to 27. Unless otherwise also listed in Section 3.2, the details given are illustrative and do not form part of the project for which consent is sought.

3.4.2 The details given are considered to represent the likely approach, given existing constraints, above-ground land uses and the operational requirements. This section describes only the main operational structures and activities with the focus on those that are relevant for the assessment of project-wide environmental effects.

3.4.3 The operational structures are described first, followed by the assumed maintenance regime.

3.4.4 Once operational the project would control the flows from 34 of the most polluting CSO discharges as identified by the EA. Flows would be diverted into the main tunnel and then via the Lee Tunnel for treatment at Beckton Sewage Treatment Works. This would include material that would otherwise have been discharged into the tidal Thames every time the existing system reaches full capacity.

Operational structures

3.4.5 For the purpose of the application, the main and long connection tunnels are shown as being located within a defined LOD in which the structure would be located (see paras. 3.2.9 to 3.2.11). These operational structures, as listed in Section 3.2 along with the relevant plans, form part of the proposed development for consent. The defined zones for the main and long connection tunnels are shown on the work plans and sections (see separate volume of figures – Section 1).

3.4.6 The approximate dimensions provided for underground structures are internal dimensions which are determined by hydraulic requirements. The internal diameter and length of the main and long connection tunnels are defined and form part of the project for consent (see Section 3.2). The following text provides additional clarification on the assumed form, purpose, function and working of these structures where this is considered helpful to the reader.

3.4.7 External dimensions of underground structures would vary depending on their thickness and the final detailed structural design. The assessment has considered the variable thickness of underground structures on a case by case basis where it may lead to a change of (or new) effects.

3.4.8 The assessment for each of the environmental topics has been based on the most appropriate dimensions and siting of these structures to ensure the assessment is robust. The approach that has been adopted in this regard is explained within each topic assessment section, where necessary.

Main tunnel

3.4.9 The tunnel alignment takes the most cost effective route from Acton Storm Tanks to the tidal Thames and then stays generally beneath the River Thames from west London to Chambers Wharf. It then diverts north easterly towards the Limehouse Cut terminating at the Abbey Mills Pumping Station site where it connects with the Lee Tunnel. The flows from the Thames Tideway Tunnel project and from Abbey Mills Pumping Station would be transported through the tunnel system for treatment at Beckton Sewage Treatment Works.

3.4.10 The main tunnel would be approximately 25km in length and the approximate depth to the invert of the tunnel would be between 30m in west London and 65m in east London. The main tunnel is defined in Section 3.2.

3.4.11 The horizontal alignment of the main tunnel would generally follow the tidal Thames where possible. This would:

a. provide an effective route to connect the CSOs that are located on both sides of the river

b. allow the use of the river for construction transport, where practicable and economic

c. minimise the number of structures that the tunnel would pass beneath, and so reduce the number of third parties affected.

3.4.12 The vertical alignment of the main tunnel is based on a shallow hydraulic gradient that is designed to provide sufficient clearance to existing tunnels and other facilities under London but also sufficient to maintain self cleaning velocities in the tunnel

3.4.13 The tunnel would receive variable inflow from the controlled CSOs depending on rainfall over the catchment. The whole tunnel would be used for storage whether the flows originate in the west or east of the catchment. The tunnel would fill from the bottom end (Beckton Sewage Treatment Works).

3.4.14 The system has been designed so that when the tunnel is nearly full, penstocks controlling flow into the tunnel would start to close to allow continued inflow from Abbey Mills Pumping Station. This reservation of tunnel storage is to ensure infrequent spills from Abbey Mills Pumping Station to the Channelsea River and for protection of the River Lee. This strategy has been agreed with the EA, and has informed the project-wide surface water assessment (see Section 14 and Vol 3 Appendix L.1).

3.4.15 It is anticipated the tunnel system would fill four times in the typical year. For most rainfall events the system would not fill.

3.4.16 When penstocks close, residual flows would be diverted to the river via the existing or relocated CSO discharge. As the tunnel system would have captured the potential discharges at all but a few of the intercepted CSOs, in most instances the residual flow would be minimal. Pumps at Beckton

Sewage Treatment Works would empty the tunnel into the head of the treatment works leaving the tunnel empty and available for the next rainfall event.

3.4.17 The volume of flow passed to the Beckton Sewage Treatment Works for treatment would be variable. Pump-out would occur when capacity at the Beckton Sewage Treatment Work is available. Combined sewage would generally be stored for less than 20 hours. The maximum time combined sewage would be stored in the typical year would be approximately 48 hours resulting from a long duration rainfall event but with some intermittent pump-out during the storm. This maximum time is shorter than the estimated time for septic conditions to occur (estimated at 60 or 70 hours).

3.4.18 Further details on the operation of the main tunnel including the air management system are provided in Vol 1 Section 2.2.

Long connection tunnels

3.4.19 Five CSOs would be intercepted by long connection tunnels, known as the Frogmore and Greenwich connection tunnels.

3.4.20 The Frogmore connection tunnel would be approximately 1,120m in length and would transfer the flows from the intercepted CSOs at King George's Park and Dormay Street, to the main tunnel at Carnwath Road Riverside.

3.4.21 The Greenwich connection tunnel would be approximately 4,600m in length and would transfer the flows from the intercepted CSOs at Greenwich Pumping Station, Deptford Church Street and Earl Pumping Station to the main tunnel at Chambers Wharf.

3.4.22 The Frogmore and Greenwich connection tunnels are defined in Section 3.2.

Typical maintenance regime

3.4.23 It is anticipated that once every ten years, a major internal inspection of the main and long connection tunnels (and other underground structures) would be required. It is likely that this would involve an expert team of inspection personnel, a small support crew with support vehicles, and two mobile cranes to lower the inspection team and equipment into the main tunnel shafts. This process would take several weeks. The larger diameter tunnel's inspection would be carried out using bespoke inspection vehicles. Where possible remotely operated vehicles with CCTV cameras would be used for inspection.

3.4.24 Operational access on an as required basis is also anticipated to deal with any blockages or other repairs/maintenance required.

3.4.25 During the maintenance period, penstocks to the tunnel would be closed off with the result that overflows could occur if rainfall events occur at the same time.

3.5 Base case and cumulative development

3.5.1 The project-wide assessments undertaken take account of other relevant development projects within the vicinity of the sites which are under construction, permitted but not yet implemented or submitted but not yet determined. In order to identify the relevant developments for consideration the Planning Inspectorate, local authorities, Greater London Authority and Transport for London (TfL) have been consulted on the methodology described in Vol 2 and asked to assist in identifying and verifying the development projects included in the assessment. Schedules are provided in Vols 4 to 27 Appendix N of the resulting development projects in the vicinity of each site, a description of what is proposed and assumptions on phasing. Longer term development projects may be included under both base case, with construction preceding that of the Thames Tideway Tunnel project, and cumulative with construction or operation occurring at the same time as the Thames Tideway Tunnel project.

3.5.2 In addition, a review of the *National Infrastructure Plan 2011* (HM Treasury, 2011)[12] and the National Infrastructure Planning website[13] has been undertaken to further inform the project-wide effects assessments. The development projects identified as part of this review and which have been included under base case, cumulative or both for the assessment of the proposed development are (further details are provided in Vol 3 Appendix A.1):

a. Crossrail

b. Thameslink

c. Northern Line Extension

d. London Olympics (Legacy Communities Scheme)

e. North London (Electricity Line) Reinforcement Project.

References

[1] Thames Water, *Preliminary environmental information report* (November 2011). Available at: http://www.thamestunnelconsultation.co.uk/document-library/catalogue-view/?c=3-preliminary-environmental-information-report. Accessed 6 January 2013

[2] Thames Water. *EIA Scoping Report* (2011). Available at: http://www.thamestunnelconsultation.co.uk/document-library/catalogue-view/?c=4-eia-scoping-report

[3] Greater London Authority. *The London Plan. Spatial Development Strategy for Greater London* (July 2011)

[4] HM Government. *National Policy Statement for Waste Water: A framework document for planning decisions on nationally significant waste water* (March 2012). Available at: http://www.defra.gov.uk/publications/files/pb13709-waste-water-nps.pdf. Accessed 2 November 2012

[5] Defra, *UK Climate Projections*: Available at: http://ukclimateprojections.defra.gov.uk/. Accessed 31 August 2012

[6] Mineral Products Association. The concrete centre. *End of Life Recycling*. Available at: ttp://www.concretecentre.com/sustainability/end_of_life_recycling.aspx. Accessed 27 November 2012.

[7] Mineral Products Association. Essential materials, sustainable solutions. *Sustainable consumption and production*. Available at: http://www.mineralproducts.org/sustainability/sustainable-products-data.html. Accessed 27 November 2012.

[8] EEF UK Steel. Key Statistics 2010. Available at: http://www.eef.org.uk/NR/rdonlyres/253B246A-CC29-44E0-AD8E-5102F9D05285/21410/KeyStatistics2014.pdf. Accessed 23 November 2012

[9] Thames Water. *Water – Planning for the Future: Draft Final Water Resources Management Plan*, (2011)

[10] Mayor of London. *Clearing the Air. The Mayor's Air Quality Strategy*. (December 2010).

[11] Thames Estuary Partnership Biodiversity Action Group. *Tidal Thames Habitat Action Plan* (undated). Available at: http://www.thamesweb.com/tep-docs/doc_download/26-tidal-thames-habitat-action-plan.html. Access 24th September 2012.

[12] HM Treasury. *National Infrastructure Plan 2011* (November 2011). Available at: http://cdn.hm-treasury.gov.uk/national_infrastructure_plan291111.pdf. Access 15 November 2012

[13] National Infrastructure Planning. Available at: http://infrastructure.planningportal.gov.uk/. Access 15 November 2012

Thames Tideway Tunnel

Environmental Statement

Volume 3: Project-wide effects assessment

Section 4: Air quality and odour

List of contents

Page number

List of tables

Page number

This page is intentionally blank

Thames Tideway Tunnel
Thames Water Utilities Limited

Application for Development Consent

Application Reference Number: WWO10001

Environmental Statement

Doc Ref: **6.2.03**

Volume 3: Project-wide effects assessment

Section 4: Air quality and odour

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

Hard copy available in

Box **17** Folder **A**
January 2013

Thames Tideway Tunnel
Creating a cleaner, healthier River Thames

This page is intentionally blank

4 Air quality and odour

4.1 Introduction

4.1.1 This section presents the findings of the assessment of the likely significant project-wide effects on air quality. This covers project-wide interactions of construction road traffic along major road corridors which could have air quality effects.

4.1.2 It is considered unlikely that there would be any significant project-wide effects on air quality from tugs pulling barges. The *Transport Assessment*, which accompanies the application for development consent (the 'application'), predicts a peak annual average of 16 barge movements per day during the peak construction period. In the context of air pollutant emissions in the vicinity of the River Thames and considering the distance of the barges from sensitive receptors and the low numbers of barge movements, the effects of emissions from tugs pulling river barges, based on professional judgement, are expected to be negligible.

4.1.3 Also there would not be any significant project-wide effects from construction plant, construction dust or on odour during construction. These aspects have therefore not been assessed.

4.1.4 The construction air quality effects at the local level around individual sites are described in Vols 4-27 Section 4.

4.1.5 Operational project-wide effects for air quality and odour have not been assessed. The specific site assessment volumes (Vols 4 to 27, Section 4) consider odour generated under conditions likely to be encountered during operation. No significant operational project-wide effects are considered likely and for this reason, only information relating to construction is presented in this assessment of project-wide effects.

4.1.6 Relevant plans and figures for the project-wide assessment are contained in a separate volume (Vol 3 Project-wide effects assessment figures).

4.2 Proposed development relevant to air quality

4.2.1 The proposed development is described in Section 3 of this volume, with further details of each site described in Section 3 of Vols 4 to 27. The elements of the proposed development relevant to air quality and the assessment of project-wide construction road traffic are set out below.

Construction

Heavy good vehicle movements

4.2.2 In accordance with *Highways Agency Design Manual for Roads and Bridges (DMRB) guidance* (Highways Agency, 2007)[1], roads which are predicted to experience an increase in annual average daily traffic (AADT) flows of 200 HGVs as a result of the Thames Tideway Tunnel project have been modelled as part of the project-wide effects assessment.

4.2.3 The A2 road corridor between Greenwich and its junction with the A220 / A223 is predicted to experience increases of more than 200 HGVs movements per day.

4.2.4 The air quality effects of construction vehicles on all other road corridors would be below the 200 HGV threshold and therefore are not considered any further as effects are expected to be negligible.

Construction worker car journeys

4.2.5 In accordance with DMRB guidance1, roads which are predicted to experience an increase in AADT flows of 1,000 vehicles as a result of the Thames Tideway Tunnel project have been modelled as part of the project-wide assessment.

4.2.6 The *Transport Assessment*, which accompanies the application, has predicted the greatest number of construction / office worker car journeys to be 108 vehicles measured as an AADT flow. There are therefore no road sections that breach the threshold outlined in the DMRB guidance and hence no further assessment is required with effects expected to be negligible.

Code of Construction Practice

4.2.7 Measures incorporated into the *Code of Construction Practice (CoCP*[i]*)* Part A (Section 5) (see Vol 1 Appendix A) to reduce transport impacts include HGV management and control measures such as designated vehicle routes to sites for construction vehicles. There is also a commitment within the *CoCP* Part A (Section 5.2) to use low emission vehicles (Euro 5) in accordance with current best environmental practice in order to limit emissions around the sites and along the route corridors.

4.2.8 The *CoCP* Part A also includes measures to control the release of construction dust. These measures include the reduction of dust produced by construction lorries such as wheel-washing and the sheeting of lorries.

4.3 Assessment methodology

4.3.1 The methodology for preparing the project-wide assessment is described in Vol 2 Environmental assessment methodology Section 4. Confirmation of the methodology used for the project-wide assessment is provided below.

Engagement

4.3.2 Vol 2 documents the overall engagement which has been undertaken in preparing the *Environmental Statement*. There are no specific comments relevant to the project-wide assessment of effects on air quality and odour.

[i] The *Code of Construction Practice* (CoCP) is provided in Vol 1 Appendix A. It contains general requirements (Part A), and site specific requirements for this site (Part B).

Baseline

4.3.3 The baseline methodology follows the methodology described in Vol 2 Section 4. There are no specific variations for identifying baseline conditions for the project-wide assessment area.

Construction

4.3.4 The assessment methodology for the assessment of construction road traffic follows that described in Vol 2 Section 4. There are no specific variations for undertaking the construction project-wide assessment.

4.3.5 As described in para. 4.2.3 above, the assessment area for the air quality project-wide assessment covers the A2 road corridor between Greenwich and its junction with the A220/A223.

4.3.6 The peak construction year in terms of construction traffic movements along the A2 road corridor according to TfL Highway Assignment Models is Project Year 3. This has been used as the year of assessment for the project-wide construction effects in which the development case (with Thames Tideway Tunnel project) has been assessed against the base case (without Thames Tideway Tunnel project) to identify likely significant effects of the Thames Tideway Tunnel project.

4.3.7 With regard to other committed developments requiring consideration in the project-wide assessment, the traffic data used for the assessment is taken from the Transport for London (TfL) Highway Assignment Models (HAM), as described in Vol 3 Section 12. The HAMS have been developed by TfL using Greater London Authority employment and population forecasts, which are based on the employment and housing projections set out in the *London Plan 2011*. As a result the HAMs and therefore the base case traffic data used for the assessment inherently take into account a level of future growth and development across London. On this basis there are no construction cumulative effects requiring assessment.

Assumptions and limitations

4.3.8 The general assumptions and limitations associated with the assessment are presented in Vol 2 Section 4. It is noted that the 2011 NO_2 data for Falconwood (GB6) have not been fully ratified. The lack of full ratification means that the characterisation of the existing baseline NO_2 concentration is less certain. However, there are no direct implications for the assessment as this concentration is not used in the assessment for verification purposes or as the background concentration used in the modelling.

4.4 Baseline conditions

4.4.1 The following section sets out the baseline conditions for air quality within the assessment area. Future baseline conditions (base case) are also described.

Current baseline

4.4.2 The current conditions with regard to local air quality are best established through long-term air quality monitoring.

4.4.3 As part of their duties under Part IV of the Environment Act 1995 (UK Government, 1995)[2], local authorities, especially in urban areas where air quality is a significant issue, undertake long-term air quality monitoring within their administrative areas.

4.4.4 There are two continuous monitoring stations and three NO_2 diffusion tube sites which collect data pertinent to the project-wide assessment area. The location of these monitoring sites is shown in Vol 3 Figure 4.4.1 (see separate volume of figures). Monitoring data for this site for the period 2007-2011 are contained in Vol 3 Table 4.4.1 (NO_2 concentrations) and Vol 3 Table 4.4.2 (PM_{10} concentrations).

4.4.5 The NO_2 monitoring at all the roadside sites indicates exceedances of the annual mean NO_2 objective / limit value (40µg/m^3). The objective / limit value is however met at the suburban site at Eltham (GR4) in all five years. The hourly objective/limit value was met for all five years at the Blackheath (GR7), Falconwood (GB6) and Eltham (GR4) sites.

4.4.6 The PM_{10} monitoring at these locations indicates that the annual mean objective / limit value has been met over the last five years where there is a valid monitoring dataset. The daily mean air quality objective for PM_{10} was exceeded in 2011 at the Blackheath (GR7) roadside site, but achieved in all other years and at the Falconwood (GB6) and Eltham (GR4) sites in all five years.

4.4.7 The monitoring results have been used to define the baseline situation and also to provide input to model verification[ii].

[ii] Model verification refers to checks that are carried out on model performance at a local level. This involves the comparison of predicted (modelled) versus measured concentrations. Where there is a disparity between the predicted and the measured concentrations, the first step should always be to check the input data and model parameters in order to minimise the errors. If required, the second step would be to determine an appropriate adjustment factor that can be applied to the modelled traffic contribution.

Vol 3 Table 4.4.1 Air quality – measured NO_2 concentrations

Monitoring site	Site type	Annual mean (µg/m3)					Number of exceedances of hourly standard				
		2011	2010	2009	2008	2007	2011	2010	2009	2008	2007
Continuous monitoring sites											
Blackheath (GR7)	Roadside	**48**	**43**	**43**	**46**	**49**	1	0	0	0	5
Falconwood (GB6)	Roadside	**42**	**51**	**45**	**41**	**48**	7	5	6	0	0
Eltham (GR4)	Suburban	23	24	24	26	30	0	4	0	0	0
Diffusion tube monitoring sites											
East Rochester Way (Bex2)	Roadside	NM	**57**	**60**	**63**	**63**	NM				
East Rochester Way (Bex3)	Roadside	**49**	**55**	**54**	**54**	**59**	NM				
East Rochester Way (Bex24)	Roadside	**57**	**60**	**60**	**67**	**71**	NM				

Note: NM indicates not measured. Emboldened figures indicate an exceedance of the objective / limit value which is 40µg/m^3 for the annual mean and 200µg/m^3 for the hourly mean which can be exceeded 18 times per year. Codes in brackets represent monitoring site identifiers used in Vol 3 Figure 4.4.1 (see separate volume of figures).

Vol 3 Table 4.4.2 Air quality – measured PM_{10} concentrations

Monitoring site	Site type	Annual mean (µg/m3)					Number of exceedances of daily standard				
		2011	2010	2009	2008	2007	2011	2010	2009	2008	2007
Blackheath (GR7)	Roadside	32	28	24 a)	IDC	27	**41**	20	12a) (40)	IDC	28
Falconwood (GB6)	Roadside	27 b)	27	23 c)	24	27	25 b) (46)	16	9 c) (35)	22	29
Eltham (GR4)	Suburban	23	23 d)	26 e)	21	19 f)	22	4 d) (34)	11e) (40)	13	4 f) (32)

Note: NM indicates not measured. Emboldened figures indicate an exceedance of the objective / limit value which is 40µg/m^3 for the annual mean and 50µg/m^3 for the daily mean which can be exceeded 35 times per year. Codes in brackets represent monitoring site identifiers used in Vol 3 Figure 4.4.1 (see separate volume of figures). IDC – Insufficient data capture.
a) Data capture for 2009 only 76%, figure in brackets for the number of exceedances is 90th percentile.
b) Data capture for 2009 only 87% figure in brackets for the number of exceedances is 90th percentile.
c) Data capture for 2009 only 75% figure in brackets for the number of exceedances is 90th percentile.
d) Data capture for 2010 only 88% figure in brackets for the number of exceedances is 90th percentile.
e) Data capture for 2010 only 87% figure in brackets for the number of exceedances is 90th percentile.
f) Data capture for 2007 only 77% figure in brackets for the number of exceedances is 90th percentile.

4.4.8 The A2 road corridor assessment area is located within the Royal Borough (RB) of Greenwich and the London Borough (LB) of Bexley. As a result of previous exceedances of air quality objectives, the RB of Greenwich and the LB of Bexley have declared their whole boroughs an Air Quality Management Area for both NO_2 and PM_{10}.

Receptors

4.4.9 As set out in Section 4.1, the air quality project-wide assessment comprises the effects on local air quality from construction road traffic. This assessment involves the selection of appropriate receptors, which are shown in Vol 3 Figure 4.4.2 to Vol 3 Figure 4.4.5 (see separate volume of figures) and detailed in the table below (Vol 3 Table 4.4.3) for the A2 road corridor assessment area. All of these receptors are relevant, albeit with different levels of sensitivity. The sensitivity of identified receptors has been determined using the criteria detailed in Vol 2 Section 4.

Vol 3 Table 4.4.3 Air quality – receptors

Receptors (relating to all identified emissions sources)	Approximate distance and direction from road corridor (m)	Receptor sensitivity to air quality (construction traffic)
Residential – Dover Court (PWR1)	13	High (exposure relevant to annual mean, daily mean and hourly mean standards)
Residential – Cade Tyler House (PWR2)	14	High (exposure relevant to annual mean, daily mean and hourly mean standards)
Residential – 130 Shooters Hill Road (PWR3)	10	High (exposure relevant to annual mean, daily mean and hourly mean standards)
Residential – Metropolitan Lodge, Shooters Hill Road (PWR4)	7	High (exposure relevant to annual mean, daily mean and hourly mean standards)
Residential – 1b-1d Shooters Hill Road (PWR5)	21	High (exposure relevant to annual mean, daily mean and hourly mean standards)
Educational - Blackheath Preparatory School Building (PWR6)	98	High (exposure relevant to annual mean, daily mean and hourly mean standards)
Educational - Blackheath Preparatory School Playing Field (PWR7)	88	Medium (exposure is relevant for the hourly mean standard only)
Educational - The Pointer School (PWR8)	118	High (exposure relevant to annual mean, daily mean and hourly mean standards)
Residential – 76 Shooters Hill Road (PWR9)	9	High (exposure relevant to annual mean, daily mean and hourly mean standards)
Residential – 78 Shooters Hill Road (PWR10)	15	High (exposure relevant to annual mean, daily mean and hourly mean standards)
Residential – Woodville, Rochester Way	14	High (exposure relevant to annual mean, daily mean and hourly

Receptors (relating to all identified emissions sources)	Approximate distance and direction from road corridor (m)	Receptor sensitivity to air quality (construction traffic)
(PWR11)		mean standards)
Residential – 28 Westbrook Road (PWR12)	25	High (exposure relevant to annual mean, daily mean and hourly mean standards)
Residential – 36 Woolacombe Road (PWR13)	50	High (exposure relevant to annual mean, daily mean and hourly mean standards)
Recreational - Kidbrooke Playing Fields (PWR14)	171	Medium (exposure is relevant for the hourly mean standard only)
Educational - Thomas Tallis School Playing Field (PWR15)	147	Medium (exposure is relevant for the hourly mean standard only)
Educational - Thomas Tallis School Building (PWR16)	189	High (exposure relevant to annual mean, daily mean and hourly mean standards)
Recreational - Kidbrooke Green Nature Reserve (PWR17)	11	Low (exposure is relevant for the hourly mean standard only)
Community - Tudway Road Surgery (PWR18)	106	Medium (exposure is relevant for the hourly mean standard only)
Community - Ferrier Library, Tellmann Square (PWR19)	141	Medium (exposure is relevant for the hourly mean standard only)
Educational - Holy Family Catholic Primary School Playing Field (PWR20)	94	Medium (exposure is relevant for the hourly mean standard only)
Educational - Holy Family Catholic Primary School Building (PWR21)	101	High (exposure relevant to annual mean, daily mean and hourly mean standards)
Community - Meadows House Nursing	79	High (exposure relevant to annual mean, daily mean and hourly

Receptors (relating to all identified emissions sources)	Approximate distance and direction from road corridor (m)	Receptor sensitivity to air quality (construction traffic)
Home (PWR22)		mean standards)
Educational – Ealdham Primary School Building (PWR23)	189	High (exposure relevant to annual mean, daily mean and hourly mean standards)
Educational – Ealdham Primary School Playing Field (PWR24)	178	Medium (exposure is relevant for the hourly mean standard only)
Recreational – Will Crooks Garden (PWR25)	16	Low (exposure is relevant for the hourly mean standard only)
Residential – 30 Will Crooks Garden (PWR26)	50	High (exposure relevant to annual mean, daily mean and hourly mean standards)
Recreational – Briset Road Park (PWR27)	27	Low (exposure is relevant for the hourly mean standard only)
Educational – Haimo Primary School Building (PWR28)	143	High (exposure relevant to annual mean, daily mean and hourly mean standards)
Educational – Haimo Primary School Playing Field (PWR29)	177	Medium (exposure is relevant for the hourly mean standard only)
Educational – University of Greenwich Athletic Ground (PWR30)	11	Low (exposure is relevant for the hourly mean standard only)
Community – Eltham Park Surgery (PWR31)	186	Medium (exposure is relevant for the hourly mean standard only)
Educational – Willow Park Montessori Day Nursery (PWR32)	94	High (exposure relevant to annual mean, daily mean and hourly mean standards)
Recreational – Eltham Park South (PWR33)	8	Low (exposure is relevant for the hourly mean standard only)

Receptors (relating to all identified emissions sources)	Approximate distance and direction from road corridor (m)	Receptor sensitivity to air quality (construction traffic)
Residential – Shepherd's Leas, Riefield Road (PWR34)	20	High (exposure relevant to annual mean, daily mean and hourly mean standards)
Residential – 30 Wincrofts Drive (PWR35)	28	High (exposure relevant to annual mean, daily mean and hourly mean standards)
Residential – 985 East Rochester Way (PWR36)	22	High (exposure relevant to annual mean, daily mean and hourly mean standards)
Residential – 9 Wellan Close (PWR37)	30	High (exposure relevant to annual mean, daily mean and hourly mean standards)
Recreational - Danson Park (PWR38)	16	Low (exposure is relevant for the hourly mean standard only)
Educational - Blackfen School for Girls Building (PWR39)	165	High (exposure relevant to annual mean, daily mean and hourly mean standards)
Educational - Blackfen School for Girls Playing Field (PWR40)	180	Medium (exposure is relevant for the hourly mean standard only)
Residential – 163 Danson Road (PWR41)	23	High (exposure relevant to annual mean, daily mean and hourly mean standards)
Residential – 89 Woodside Lane (PWR42)	18	High (exposure relevant to annual mean, daily mean and hourly mean standards)
Recreational – Bexleyheath Golf Course (PWR43)	24	Low (exposure is relevant for the hourly mean standard only)
Educational – Upton County Primary School Playing Field (PWR44)	88	Medium (exposure is relevant for the hourly mean standard only)
Educational – Upton County Primary	156	High (exposure relevant to annual mean, daily mean and hourly

Receptors (relating to all identified emissions sources)	Approximate distance and direction from road corridor (m)	Receptor sensitivity to air quality (construction traffic)
School Building (PWR45)		mean standards)
Educational – Townley Grammar School for Girls Building (PWR46)	118	High (exposure relevant to annual mean, daily mean and hourly mean standards)
Educational – Townley Grammar School for Girls Playing Field (PWR47)	133	Medium (exposure is relevant for the hourly mean standard only)
Residential – 1 Arundel Close (PWR48)	15	High (exposure relevant to annual mean, daily mean and hourly mean standards)
Educational – Beths Grammar School Building (PWR49)	61	High (exposure relevant to annual mean, daily mean and hourly mean standards)
Educational – Beths Grammar School Playing Field (PWR50)	30	Medium (exposure is relevant for the hourly mean standard only)

Construction base case

4.4.10 The base case conditions for the construction assessment year would change from the current conditions due to modifications to the sources of the air pollution in the intervening period.

4.4.11 For road vehicles, there would be an increase in the penetration of new Euro emissions standards (Defra, 2012)[3] to the London vehicle fleet between the current situation and Project Year 3 of construction. Euro standards define the acceptable exhaust emission limits for new vehicles sold in the EU. These standards are defined through a series of European Union directives staging the progressive introduction of increasingly stringent standards over time. The uptake of newer vehicles with improved emission controls should lead to a reduction in NO_2 and PM_{10} concentrations over time. These changes in fleet composition and the emissions are covered in this assessment.

4.4.12 Other emissions sources should also reduce due to local and national policies. Therefore, the non-road sources of the background concentrations used in the modelling have been reduced in line with Defra guidance LAQM.TG(09) (Defra, 2009)[4]. Background pollutant concentrations for Project Year 3 of construction (peak construction year) used in the modelling are shown in Vol 3 Table 4.4.4.

4.4.13 The background NO_2 and PM_{10} concentrations have been derived from the 2010 annual means measured at the suburban site at Eltham (GR4).

Vol 3 Table 4.4.4 Air quality – annual mean background pollutant concentrations

Pollutant	Baseline (2010)	Peak construction year (Project Year 3 of construction)
NO_2 (µg/m^3)*	24.0	17.4
PM_{10} (µg/m^3)*	22.1	20.1

*Note: * Taken from monitoring site at Eltham (GR4).*

4.5 Construction effects assessment

4.5.1 Construction effects on local air quality from construction road traffic have been assessed following the modelling methodology set out in Vol 2 Section 4. This involves predicting NO_2 and PM_{10} concentrations in the baseline year (2010), and in the peak construction year (Project Year 3 of construction) without the proposed development (base case) and with the proposed development (development case). Predicted pollutant concentrations for the base case and development case can then be compared to determine the air quality impacts associated with the project and considering these in the context of statutory air quality objectives/limit values to determine the significance of effects at specified receptors (listed in Vol 3 Table 4.4.3).

4.5.2 The assessment has focussed on NO_2 and PM_{10} concentrations as these are the only pollutants whose air quality standards may be exceeded.

From professional experience, emissions of other pollutants (eg, volatile organic compounds (VOCs)) are very unlikely to be significant and therefore do not need to be assessed.

4.5.3 A model verification[iii] exercise has been undertaken along the A2 road corridor in line with the Defra guidance LAQM.TG(09)4. For NO_2, this checks the model performance against measured concentrations, using five local authority monitoring sites (GR7, GB6, Bex2, Bex3 and Bex24 – see Vol 3 Table 4.4.1). For PM_{10}, the model performance was checked against measured concentration at the Falconwood (GB6) site (see Vol 3 Table 4.4.2).

4.5.4 Further details regarding the verification process are included in Vol 3 Appendix B.1. The model adjustment factors derived from the verification process were applied to NO_2 and PM_{10} results as appropriate.

4.5.5 The model inputs for the local air quality assessment for the project-wide assessment are also detailed in Vol 3 Appendix B.2. This includes road traffic data (comprising annual average daily traffic flows, heavy good vehicle proportions and speeds for each road link).

NO_2 concentrations

4.5.6 Predicted annual mean NO_2 concentrations for the modelled scenarios are shown in Vol 3 Table 4.5.1. This table details the forecast NO_2 concentrations at specific sensitive receptors. Annual mean results are shown for all of the sensitive receptors but the receptors are divided into two groups depending the annual mean objective/limit value applies or not. The annual mean criteria only apply at those receptors which could be occupied continually for a year (eg, residential properties). Exceedances of the hourly objective / limit value are inferred from the annual mean concentration.

4.5.7 The modelled concentrations in Vol 3 Table 4.5.1 show that annual mean NO_2 levels are predicted to decrease between 2010 and the project-wide assessment year with or without the Thames Tideway Tunnel project. This decrease is due to predicted reductions in background concentrations and improved vehicle engine technology. The results for the development case show small increases over the base case at the majority of modelled receptors due to the construction traffic along the A2 road corridor.

4.5.8 Exceedances of the annual mean objective / limit value (40µg/m^3) are predicted for a number of receptors in all scenarios. In line with LAQM.TG(09)4, modelled concentrations above 60µg/m^3 indicate exceedances of the hourly NO_2 air quality objective / limit value. Therefore, exceedances of the hourly objective / limit value are considered likely at Eltham Park South (PWR33) and the residential property at 1 Arundel Close (PWR48) in the baseline case. No exceedances of the

[iii] Model verification refers to checks that are carried out on model performance at a local level. This involves the comparison of predicted (modelled) versus measured concentrations. Where there is a disparity between the predicted and the measured concentrations, the first step should always be to check the input data and model parameters in order to minimise the errors. If required, the second step would be to determine an appropriate adjustment factor that can be applied to the modelled traffic contribution.

hourly NO_2 air quality objective / limit value are predicted in the base and development cases.

Vol 3 Table 4.5.1 Air quality – predicted annual mean NO_2 concentrations

Receptor	Predicted annual mean NO_2 concentration ($\mu g/m^3$)			Change between base and dev cases ($\mu g/m^3$)	Magnitude of impact
	2010 baseline	Base case	Dev case		
Receptors where the annual mean objective / limit value applies					
Dover Court residential (PWR1)	**43.1**	31.4	32.2	0.8	Small
Cade Tyler House residential (PWR2)	38.9	28.2	28.7	0.5	Small
130 Shooters Hill Road residential (PWR3)	**41.9**	30.3	31.0	0.8	Small
Metropolitan Lodge, Shooters Hill Road residential (PWR4)	**41.9**	29.9	30.2	0.3	Negligible
1b-1d Shooters Hill Road residential (PWR5)	34.8	24.5	24.9	0.3	Negligible
Blackheath Preparatory School Building (PWR6)	30.4	21.7	22.0	0.3	Negligible
The Pointer School (PWR8)	27.5	19.7	19.8	0.1	Negligible
76 Shooters Hill Road residential (PWR9)	**53.4**	39.2	**40.5**	1.3	Small
78 Shooters Hill Road residential (PWR10)	**48.6**	35.1	35.7	0.6	Small
Woodville, Rochester Way residential (PWR11)	**55.1**	**40.4**	**40.9**	0.5	Small
28 Westbrook Road residential (PWR12)	**43.4**	30.1	30.2	0.1	Negligible
36 Woolacombe Road residential (PWR13)	38.1	26.3	26.4	0.1	Negligible
Thomas Tallis School Building (PWR16)	29.2	20.5	20.5	0.0	Negligible
Holy Family Catholic Primary School Building (PWR21)	30.8	21.4	21.4	0.1	Negligible

Receptor	Predicted annual mean NO_2 concentration (µg/m³)			Change between base and dev cases (µg/m³)	Magnitude of impact
	2010 baseline	Base case	Dev case		
Meadows House Nursing Home (PWR22)	32.5	22.4	22.5	0.1	Negligible
Ealdham Primary School Building (PWR23)	29.3	20.3	20.4	0.1	Negligible
30 Will Crooks Garden residential (PWR26)	35.8	24.5	24.6	0.1	Negligible
Haimo Primary School Building (PWR28)	30.9	21.6	21.7	0.1	Negligible
Willow Park Montessori Day Nursery (PWR32)	37.9	26.3	26.4	0.1	Negligible
Shepherd's Leas, Riefield Road residential (PWR34)	**54.5**	38.5	38.8	0.3	Negligible
30 Wincrofts Drive residential (PWR35)	**48.5**	33.9	33.9	0.1	Negligible
985 East Rochester Way residential (PWR36)	**52.8**	37.0	37.2	0.2	Negligible
9 Wellan Close residential (PWR37)	**44.5**	30.8	30.8	0.1	Negligible
Blackfen School for Girls Building (PWR39)	33.0	23.0	23.1	0.0	Negligible
163 Danson Road residential (PWR41)	**47.0**	33.0	33.3	0.3	Negligible
89 Woodside Lane residential (PWR42)	**54.4**	38.7	39.0	0.3	Negligible
Upton County Primary School Building (PWR45)	30.7	21.7	21.8	0.1	Negligible
Townley Grammar School for Girls Building (PWR46)	32.1	22.6	22.6	0.1	Negligible
1 Arundel Close residential (PWR48)	**62.8**	**45.3**	**45.6**	0.3	Negligible
Beths Grammar School Building (PWR49)	**42.6**	29.6	29.8	0.2	Negligible
Receptors where the annual mean objective / limit value does not apply					
Blackheath Preparatory School Playing Field	31.3	22.3	22.5	0.2	Negligible

Receptor	Predicted annual mean NO_2 concentration (µg/m³)			Change between base and dev cases (µg/m³)	Magnitude of impact
	2010 baseline	Base case	Dev case		
(PWR7)					
Kidbrooke Playing Fields (PWR14)	30.0	20.9	21.0	0.1	Negligible
Thomas Tallis School Playing Field (PWR15)	30.1	21.1	21.1	0.1	Negligible
Kidbrooke Green Nature Reserve (PWR17)	**57.1**	**40.6**	**40.8**	0.2	Negligible
Tudway Road Surgery (PWR18)	30.9	21.5	21.7	0.2	Negligible
Ferrier Library, Tellmann Square (PWR19)	29.9	21.0	21.1	0.1	Negligible
Holy Family Catholic Primary School Playing Field (PWR20)	32.0	22.2	22.3	0.1	Negligible
Ealdham Primary School Playing Field (PWR24)	29.5	20.5	20.7	0.2	Negligible
Will Crooks Garden (PWR25)	**46.9**	31.8	32.0	0.2	Negligible
Briset Road Park (PWR27)	**41.1**	27.9	28.1	0.1	Negligible
Haimo Primary School Playing Field (PWR29)	30.1	21.1	21.2	0.1	Negligible
University of Greenwich Athletic Ground (PWR30)	**59.5**	**42.4**	**42.6**	0.2	Negligible
Eltham Park Surgery (PWR31)	32.2	22.5	22.5	0.0	Negligible
Eltham Park South (PWR33)	**65.1**	**46.8**	**47.1**	0.2	Negligible
Danson Park (PWR38)	**59.9**	**42.7**	**42.9**	0.3	Negligible
Blackfen School for Girls Playing Field (PWR40)	32.5	22.6	22.9	0.3	Negligible
Bexleyheath Golf Course (PWR43)	**52.0**	36.7	37.0	0.3	Negligible
Upton County Primary School Playing Field	34.1	23.9	24.0	0.1	Negligible

Receptor	Predicted annual mean NO_2 concentration ($\mu g/m^3$)			Change between base and dev cases ($\mu g/m^3$)	Magnitude of impact
	2010 baseline	Base case	Dev case		
(PWR44)					
Townley Grammar School for Girls Playing Field (PWR47)	31.7	22.3	22.3	0.0	Negligible
Beths Grammar School Playing Field (PWR50)	**53.5**	37.9	38.2	0.3	Negligible

Note: Emboldened figures indicate an exceedance of the criteria which is 40µg/m³ for the annual mean. Changes at each receptor have been rounded to one decimal place.

4.5.9 The highest predicted increase in annual mean concentration as a result of the Thames Tideway Tunnel project construction traffic along the A2 corridor is 1.3µg/m³ which is predicted at the residential property at 76 Shooters Hill Road (PWR9). This increase is described as small magnitude according to the criteria detailed in Vol 2 Section 4.

4.5.10 The significance of the effect at the high sensitivity receptors with a small magnitude of impact and concentrations above 36µg/m³ is **minor adverse** (according to the criteria detailed in Vol 2 Section 4). The significance of the effect at the high sensitivity receptors with a small magnitude of impact and concentrations below 36µg/m³ or with a negligible magnitude of impact is **negligible**. The significance of the effect at the medium and low sensitivity receptors, which all have a negligible magnitude of impact, is **negligible**.

PM_{10} concentrations

4.5.11 Predicted annual mean PM_{10} concentrations for the modelled scenarios are shown in Vol 3 Table 4.5.2. This table details the forecast PM_{10} concentrations at specific sensitive receptors.

4.5.12 The modelled concentrations in Vol 3 Table 4.5.2 show that annual mean concentrations of PM_{10} are predicted to achieve the annual mean objective / limit value (40µg/m³) in all modelled scenarios and decrease between 2010 and the project-wide assessment year with or without the Thames Tideway Tunnel project. This decrease is due to predicted reductions in background concentrations and improved vehicle engine technology. The predicted results for the development case show no increases over the base case due to Thames Tideway Tunnel project construction traffic along the A2 road corridor, except at receptor PWR9, the residential property at 76 Shooters Hill Road, where the increase is 0.1µg/m³, which is a negligible magnitude of impact.

Vol 3 Table 4.5.2 Air quality – predicted annual mean PM_{10} concentrations

Receptor	Predicted annual mean PM_{10} concentration (µg/m^3)			Change between base and dev cases (µg/m^3)	Magnitude of impact
	2010 baseline	Base case	Dev case		
Receptors where the annual mean objective / limit value applies					
Dover Court residential (PWR1)	24.2	21.6	21.6	0.0	Negligible
Cade Tyler House residential (PWR2)	23.7	21.3	21.4	0.0	Negligible
130 Shooters Hill Road residential (PWR3)	24.2	22.0	22.1	0.0	Negligible
Metropolitan Lodge, Shooters Hill Road residential (PWR4)	24.3	21.9	22.0	0.0	Negligible
1b-1d Shooters Hill Road residential (PWR5)	23.4	21.1	21.2	0.0	Negligible
Blackheath Preparatory School Building (PWR6)	22.8	20.7	20.7	0.0	Negligible
The Pointer School (PWR8)	22.5	20.4	20.4	0.0	Negligible
76 Shooters Hill Road residential (PWR9)	26.0	22.9	23.0	0.1	Negligible
78 Shooters Hill Road residential (PWR10)	25.4	22.8	22.8	0.0	Negligible
Woodville, Rochester Way residential (PWR11)	26.6	23.9	23.9	0.0	Negligible
28 Westbrook Road residential (PWR12)	25.1	22.6	22.7	0.0	Negligible
36 Woolacombe Road residential (PWR13)	24.2	21.9	21.9	0.0	Negligible
Thomas Tallis School Building (PWR16)	22.8	20.7	20.7	0.0	Negligible
Holy Family Catholic Primary School Building (PWR21)	23.0	20.9	20.9	0.0	Negligible
Meadows House Nursing Home (PWR22)	23.3	21.1	21.1	0.0	Negligible

Receptor	Predicted annual mean PM_{10} concentration (µg/m³)			Change between base and dev cases (µg/m³)	Magnitude of impact
	2010 baseline	Base case	Dev case		
Ealdham Primary School Building (PWR23)	22.8	20.7	20.7	0.0	Negligible
30 Will Crooks Garden residential (PWR26)	23.8	21.5	21.6	0.0	Negligible
Haimo Primary School Building (PWR28)	23.0	20.9	20.9	0.0	Negligible
Willow Park Montessori Day Nursery (PWR32)	24.0	21.8	21.8	0.0	Negligible
Shepherd's Leas, Riefield Road residential (PWR34)	27.1	24.5	24.6	0.0	Negligible
30 Wincrofts Drive residential (PWR35)	26.0	23.5	23.5	0.0	Negligible
985 East Rochester Way residential (PWR36)	26.9	24.3	24.3	0.0	Negligible
9 Wellan Close residential (PWR37)	25.3	22.8	22.9	0.0	Negligible
Blackfen School for Girls Building (PWR39)	23.4	21.2	21.2	0.0	Negligible
163 Danson Road residential (PWR41)	25.6	23.2	23.3	0.0	Negligible
89 Woodside Lane residential (PWR42)	27.1	24.5	24.6	0.0	Negligible
Upton County Primary School Building (PWR45)	23.0	20.9	20.9	0.0	Negligible
Townley Grammar School for Girls Building (PWR46)	23.2	21.0	21.0	0.0	Negligible
1 Arundel Close residential (PWR48)	29.0	26.1	26.1	0.0	Negligible
Beths Grammar School Building (PWR49)	24.8	22.4	22.5	0.0	Negligible
Receptors where the annual mean objective / limit value does not apply					
Blackheath Preparatory School Playing Field (PWR7)	22.9	20.8	20.8	0.0	Negligible

Receptor	Predicted annual mean PM_{10} concentration (µg/m^3)			Change between base and dev cases (µg/m^3)	Magnitude of impact
	2010 baseline	Base case	Dev case		
Kidbrooke Playing Fields (PWR14)	22.9	20.8	20.8	0.0	Negligible
Thomas Tallis School Playing Field (PWR15)	22.9	20.8	20.8	0.0	Negligible
Kidbrooke Green Nature Reserve (PWR17)	27.6	24.9	24.9	0.0	Negligible
Tudway Road Surgery (PWR18)	23.0	20.9	20.9	0.0	Negligible
Ferrier Library, Tellmann Square (PWR19)	22.9	20.7	20.7	0.0	Negligible
Holy Family Catholic Primary School Playing Field (PWR20)	23.2	21.0	21.0	0.0	Negligible
Ealdham Primary School Playing Field (PWR24)	22.8	20.7	20.7	0.0	Negligible
Will Crooks Garden (PWR25)	25.8	23.2	23.2	0.0	Negligible
Briset Road Park (PWR27)	24.7	22.3	22.3	0.0	Negligible
Haimo Primary School Playing Field (PWR29)	22.9	20.8	20.8	0.0	Negligible
University of Greenwich Athletic Ground (PWR30)	28.2	25.5	25.5	0.0	Negligible
Eltham Park Surgery (PWR31)	23.2	21.0	21.0	0.0	Negligible
Eltham Park South (PWR33)	29.5	26.6	26.7	0.0	Negligible
Danson Park (PWR38)	28.5	25.7	25.7	0.0	Negligible
Blackfen School for Girls Playing Field (PWR40)	23.3	21.1	21.1	0.0	Negligible
Bexleyheath Golf Course (PWR43)	26.7	24.1	24.1	0.0	Negligible
Upton County Primary School Playing Field (PWR44)	23.5	21.3	21.3	0.0	Negligible

Receptor	Predicted annual mean PM_{10} concentration (µg/m^3)			Change between base and dev cases (µg/m^3)	Magnitude of impact
	2010 baseline	Base case	Dev case		
Townley Grammar School for Girls Playing Field (PWR47)	23.1	21.0	21.0	0.0	Negligible
Beths Grammar School Playing Field (PWR50)	26.8	24.2	24.2	0.0	Negligible

Note: Changes at each receptor have been rounded to one decimal place.

4.5.13 As predicted PM_{10} concentrations are well below the annual mean PM_{10} standard (40 µg/m^3), the significance of the effects is **negligible** at all receptors.

4.5.14 With regard to the daily mean PM_{10} concentrations, Vol 3 Table 4.5.3 shows the predicted number exceedances of the daily PM_{10} standard (50µg/m^3) for each modelled scenario. The objective / limit value allows no more than 35 exceedances in a year.

Vol 3 Table 4.5.3 Air quality – predicted exceedances of the daily PM_{10} standard

Receptor	Predicted number of exceedances of the daily PM_{10} standard			Change between base and dev cases (days)	Magnitude of impact
	2010 baseline	Base case	Dev case		
Receptors where the daily objective / limit value applies					
Dover Court residential (PWR1)	10	6	6	0	Negligible
Cade Tyler House residential (PWR2)	9	5	5	0	Negligible
130 Shooters Hill Road residential (PWR3)	11	6	6	0	Negligible
Metropolitan Lodge, Shooters Hill Road residential (PWR4)	11	6	6	0	Negligible
1b-1d Shooters Hill Road residential (PWR5)	9	5	5	0	Negligible
Blackheath Preparatory School Building (PWR6)	8	4	4	0	Negligible
The Pointer School	8	4	4	0	Negligible

Receptor	Predicted number of exceedances of the daily PM_{10} standard			Change between base and dev cases (days)	Magnitude of impact
	2010 baseline	Base case	Dev case		
(PWR8)					
76 Shooters Hill Road residential (PWR9)	7	4	4	0	Negligible
78 Shooters Hill Road residential (PWR10)	15	8	8	0	Negligible
Woodville, Rochester Way residential (PWR11)	13	8	8	0	Negligible
28 Westbrook Road residential (PWR12)	17	10	10	0	Negligible
36 Woolacombe Road residential (PWR13)	13	7	7	0	Negligible
Thomas Tallis School Building (PWR16)	8	4	4	0	Negligible
Holy Family Catholic Primary School Building (PWR21)	8	5	5	0	Negligible
Meadows House Nursing Home (PWR22)	9	5	5	0	Negligible
Ealdham Primary School Building (PWR23)	8	4	4	0	Negligible
30 Will Crooks Garden residential (PWR26)	10	6	6	0	Negligible
Haimo Primary School Building (PWR28)	8	5	5	0	Negligible
Willow Park Montessori Day Nursery (PWR32)	10	6	6	0	Negligible
Shepherd's Leas, Riefield Road residential (PWR34)	18	11	11	0	Negligible
30 Wincrofts Drive residential (PWR35)	15	9	9	0	Negligible
985 East Rochester Way residential (PWR36)	17	11	11	0	Negligible
9 Wellan Close residential (PWR37)	13	8	8	0	Negligible

Receptor	Predicted number of exceedances of the daily PM_{10} standard			Change between base and dev cases (days)	Magnitude of impact
	2010 baseline	Base case	Dev case		
Blackfen School for Girls Building (PWR39)	9	5	5	0	Negligible
163 Danson Road residential (PWR41)	14	9	9	0	Negligible
89 Woodside Lane residential (PWR42)	18	11	11	0	Negligible
Upton County Primary School Building (PWR45)	9	5	5	0	Negligible
Townley Grammar School for Girls Building (PWR46)	8	5	5	0	Negligible
1 Arundel Close residential (PWR48)	24	15	15	0	Negligible
Beths Grammar School Building (PWR49)	12	7	7	0	Negligible
Receptors where the daily objective / limit value does not apply					
Blackheath Preparatory School Playing Field (PWR7)	8	4	4	0	Negligible
Kidbrooke Playing Fields (PWR14)	8	4	4	0	Negligible
Thomas Tallis School Playing Field (PWR15)	8	4	4	0	Negligible
Kidbrooke Green Nature Reserve (PWR17)	19	12	12	0	Negligible
Tudway Road Surgery (PWR18)	8	5	5	0	Negligible
Ferrier Library, Tellmann Square (PWR19)	8	4	4	0	Negligible
Holy Family Catholic Primary School Playing Field (PWR20)	8	5	5	0	Negligible
Ealdham Primary School Playing Field (PWR24)	8	4	4	0	Negligible
Will Crooks Garden	14	9	9	0	Negligible

Receptor	Predicted number of exceedances of the daily PM_{10} standard			Change between base and dev cases (days)	Magnitude of impact
	2010 baseline	Base case	Dev case		
(PWR25)					
Briset Road Park (PWR27)	12	7	7	0	Negligible
Haimo Primary School Playing Field (PWR29)	8	4	4	0	Negligible
University of Greenwich Athletic Ground (PWR30)	21	14	14	0	Negligible
Eltham Park Surgery (PWR31)	8	5	5	0	Negligible
Eltham Park South (PWR33)	26	17	17	0	Negligible
Danson Park (PWR38)	22	14	14	0	Negligible
Blackfen School for Girls Playing Field (PWR40)	9	5	5	0	Negligible
Bexleyheath Golf Course (PWR43)	17	10	10	0	Negligible
Upton County Primary School Playing Field (PWR44)	9	5	5	0	Negligible
Townley Grammar School for Girls Playing Field (PWR47)	8	5	5	0	Negligible
Beths Grammar School Playing Field (PWR50)	17	11	11	0	Negligible

Note: Changes at each receptor have been rounded to the nearest whole number.

4.5.15 The results in Vol 3 Table 4.5.3 show that the number of daily exceedances of PM_{10} is predicted to decrease between 2010 and the project-wide assessment year with or without the Thames Tideway Tunnel project. This decrease is due to predicted reductions in background concentrations and improved vehicle engine technology. The predicted results for the development case show no increases compared with the base case at the modelled receptors due to Thames Tideway Tunnel project construction traffic along the A2 road corridor.

4.5.16 With no exceedances of the daily PM_{10} criteria in the development case, the significance of the effects would be **negligible** at all sensitive receptors.

4.5.17 Overall, the results of the assessment show that there would be no significant construction effects along the A2 road corridor.

Sensitivity test of Transport Strategy

4.5.18 The project-wide effects assessment is based on the transport figures set out in the *Transport Strategy*. A sensitivity test of these figures is contained in Vol 3 Appendix J.

4.6 Operational effects assessment

4.6.1 As described in para. 4.1.5, operational effects have not been considered in the project-wide effects assessment.

4.7 Cumulative effects assessment

4.7.1 As explained in para. 4.3.7, there are no specific project-wide cumulative effects to assess.

4.8 Mitigation

4.8.1 Control measures of relevance to air quality are embedded in the *CoCP* Part A (see Vol 1 Appendix A) as summarised in Section 4.2. No mitigation is required as no significant project-wide air quality effects are predicted.

4.9 Residual effects assessment

Construction effects

4.9.1 As no mitigation measures are required, the residual construction effects remain as described in Section 4.5. All residual effects are presented in Section 4.10.

4.10 Project-wide effects assessment summary

Vol 3 Table 4.10.1 Air quality – summary of construction assessment

Receptor	Effect	Significance of effect	Mitigation	Significance of residual effect
Residential – Dover Court (PWR1)	Local air quality – effects from construction road traffic	Negligible	None	Negligible
Residential – Cade Tyler House (PWR2)	Local air quality – effects from construction road traffic	Negligible	None	Negligible
Residential – 130 Shooters Hill Road (PWR3)	Local air quality – effects from construction road traffic	Negligible	None	Negligible
Residential – Metropolitan Lodge, Shooters Hill Road (PWR4)	Local air quality – effects from construction road traffic	Negligible	None	Negligible
Residential – 1b-1d Shooters Hill Road (PWR5)	Local air quality – effects from construction road traffic	Negligible	None	Negligible
Educational - Blackheath Preparatory School Building (PWR6)	Local air quality – effects from construction road traffic	Negligible	None	Negligible
Educational - Blackheath Preparatory School Playing Field (PWR7)	Local air quality – effects from construction road traffic	Negligible	None	Negligible
Educational - The Pointer School (PWR8)	Local air quality – effects from construction road traffic	Negligible	None	Negligible
Residential – 76 Shooters Hill Road (PWR9)	Local air quality – effects from construction road traffic	Minor adverse	None	Minor adverse
Residential – 78 Shooters Hill Road (PWR10)	Local air quality – effects from construction road traffic	Negligible	None	Negligible

Receptor	Effect	Significance of effect	Mitigation	Significance of residual effect
Residential – Woodville, Rochester Way (PWR11)	Local air quality – effects from construction road traffic	Minor adverse	None	Minor adverse
Residential – 28 Westbrook Road (PWR12)	Local air quality – effects from construction road traffic	Negligible	None	Negligible
Residential – 36 Woolacombe Road (PWR13)	Local air quality – effects from construction road traffic	Negligible	None	Negligible
Recreational - Kidbrooke Playing Fields (PWR14)	Local air quality – effects from construction road traffic	Negligible	None	Negligible
Educational - Thomas Tallis School Playing Field (PWR15)	Local air quality – effects from construction road traffic	Negligible	None	Negligible
Educational - Thomas Tallis School Building (PWR16)	Local air quality – effects from construction road traffic	Negligible	None	Negligible
Recreational - Kidbrooke Green Nature Reserve (PWR17)	Local air quality – effects from construction road traffic	Negligible	None	Negligible
Community - Tudway Road Surgery (PWR18)	Local air quality – effects from construction road traffic	Negligible	None	Negligible
Community - Ferrier Library, Tellmann Square (PWR19)	Local air quality – effects from construction road traffic	Negligible	None	Negligible
Educational - Holy Family Catholic Primary School Playing Field (PWR20)	Local air quality – effects from construction road traffic	Negligible	None	Negligible
Educational - Holy Family Catholic Primary School Building (PWR21)	Local air quality – effects from construction road traffic	Negligible	None	Negligible
Community - Meadows House Nursing Home (PWR22)	Local air quality – effects from construction road traffic	Negligible	None	Negligible

Receptor	Effect	Significance of effect	Mitigation	Significance of residual effect
Educational - Ealdham Primary School Building (PWR23)	Local air quality – effects from construction road traffic	Negligible	None	Negligible
Educational - Ealdham Primary School Playing Field (PWR24)	Local air quality – effects from construction road traffic	Negligible	None	Negligible
Recreational - Will Crooks Garden (PWR25)	Local air quality – effects from construction road traffic	Negligible	None	Negligible
Residential – 30 Will Crooks Garden (PWR26)	Local air quality – effects from construction road traffic	Negligible	None	Negligible
Recreational - Briset Road Park (PWR27)	Local air quality – effects from construction road traffic	Negligible	None	Negligible
Educational - Haimo Primary School Building (PWR28)	Local air quality – effects from construction road traffic	Negligible	None	Negligible
Educational - Haimo Primary School Playing Field (PWR29)	Local air quality – effects from construction road traffic	Negligible	None	Negligible
Educational - University of Greenwich Athletic Ground (PWR30)	Local air quality – effects from construction road traffic	Negligible	None	Negligible
Community - Eltham Park Surgery (PWR31)	Local air quality – effects from construction road traffic	Negligible	None	Negligible
Educational - Willow Park Montessori Day Nursery (PWR32)	Local air quality – effects from construction road traffic	Negligible	None	Negligible
Recreational - Eltham Park South (PWR33)	Local air quality – effects from construction road traffic	Negligible	None	Negligible
Residential – Shepherd's Leas, Riefield Road (PWR34)	Local air quality – effects from construction road traffic	Negligible	None	Negligible

Receptor	Effect	Significance of effect	Mitigation	Significance of residual effect
Residential – 30 Wincrofts Drive (PWR35)	Local air quality – effects from construction road traffic	Negligible	None	Negligible
Residential – 985 East Rochester Way (PWR36)	Local air quality – effects from construction road traffic	Negligible	None	Negligible
Residential – 9 Wellan Close (PWR37)	Local air quality – effects from construction road traffic	Negligible	None	Negligible
Recreational - Danson Park (PWR38)	Local air quality – effects from construction road traffic	Negligible	None	Negligible
Educational - Blackfen School for Girls Building (PWR39)	Local air quality – effects from construction road traffic	Negligible	None	Negligible
Educational - Blackfen School for Girls Playing Field (PWR40)	Local air quality – effects from construction road traffic	Negligible	None	Negligible
Residential – 163 Danson Road (PWR41)	Local air quality – effects from construction road traffic	Negligible	None	Negligible
Residential – 89 Woodside Lane (PWR42)	Local air quality – effects from construction road traffic	Negligible	None	Negligible
Recreational - Bexleyheath Golf Course (PWR43)	Local air quality – effects from construction road traffic	Negligible	None	Negligible
Educational - Upton County Primary School Playing Field (PWR44)	Local air quality – effects from construction road traffic	Negligible	None	Negligible
Educational - Upton County Primary School Building (PWR45)	Local air quality – effects from construction road traffic	Negligible	None	Negligible
Educational - Townley Grammar School for Girls Building (PWR46)	Local air quality – effects from construction road traffic	Negligible	None	Negligible

Receptor	Effect	Significance of effect	Mitigation	Significance of residual effect
Educational - Townley Grammar School for Girls Playing Field (PWR47)	Local air quality – effects from construction road traffic	Negligible	None	Negligible
Residential – 1 Arundel Close (PWR48)	Local air quality – effects from construction road traffic	Negligible	None	Negligible
Educational - Beths Grammar School Building (PWR49)	Local air quality – effects from construction road traffic	Negligible	None	Negligible
Educational - Beths Grammar School Playing Field (PWR50)	Local air quality – effects from construction road traffic	Negligible	None	Negligible

4.11 Summary of significant effects at all sites

4.11.1 As summarised in Vol 3 Table 4.11.1, the assessment has identified some significant effects on air quality as a result of the Thames Tideway Tunnel project. Significant beneficial effects are predicted at the relocated vessels at the Victoria Embankment Foreshore and Blackfriars Bridge Foreshore sites. This is a result of the new locations being further from major roads than current their locations. Significant adverse effects are predicted at receptors close to the Shad Thames Pumping Station and Bekesbourne Street sites. It is not possible to propose any specific mitigation measures to address these significant effects as best practice emission limits are already committed to (see *CoCP* Part A) and it is not currently possible to identify means of reducing NOx emissions further.

4.11.2 At all other sites and receptors no significant adverse effects are predicted during construction, with the implementation of the measures set out in the *CoCP* effectively minimising effects on local air quality and dust.

4.11.3 No significant odour effects are predicted during the operation of the Thames Tideway Tunnel project.

Vol 3 Table 4.11.1 Air quality – summary of significant effects at all sites

Significance of effect	Receptor	Description of effect	Sites with significant effects (pre-mitigation)	Sites with significant residual effects
Construction - adverse	Residential	Local air quality-effects from construction road traffic and plant emissions	Shad Thames Pumping Station (Wheat Wharf and Tamarind Court receptors only) (see Vol 19 Section 4) Bekesbourne Street (8 Bekesbourne Street receptor only) (see Vol 27 Section 4)	Shad Thames Pumping Station (Wheat Wharf and Tamarind Court receptors only) (see Vol 19 Section 4) Bekesbourne Street (8 Bekesbourne Street receptor only) (see Vol 27 Section 4)
Construction – beneficial	Restaurant / Bar	Local air quality-effects from construction road traffic and plant emissions	Victoria Embankment Foreshore (relocated Tattershall Castle receptor only) (see Vol 17 Section 4) Blackfriars Bridge Foreshore (relocated President vessel receptor only) (see Vol 18 Section 4)	Victoria Embankment Foreshore (relocated Tattershall Castle receptor only) (see Vol 17 Section 4) Blackfriars Bridge Foreshore (relocated President vessel receptor only) (see Vol 18 Section 4)

References

[1] Highways Agency. *Design Manual for Roads and Bridges*, Volume 11 Environmental Assessment, Section 3 Environmental Assessment Techniques, Part 1 HA207/07 Air Quality (May 2007).

[2] UK Government. *Environment Act 1995*. Available at: http://www.legislation.gov.uk/ukpga/1995/25/contents. Accessed June 2012.

[3] Defra. Emissions. Available at: http://laqm.defra.gov.uk/review-and-assessment/tools/emissions.html#eft. Accessed June 2012.

[4] Defra. *Local Air Quality Management- Technical Guidance*, LAQM.TG(09) (2009).

Thames Tideway Tunnel
Thames Water Utilities Limited

Application for Development Consent

Application Reference Number: WWO10001

Environmental Statement

Doc Ref: **6.2.03**

Volume 3: Project-wide effects assessment

Section 5: Ecology - aquatic

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

Hard copy available in

Box **17** Folder **A**
January 2013

Thames Tideway Tunnel
Creating a cleaner, healthier River Thames

This page is intentionally blank

Thames Tideway Tunnel

Environmental Statement

Volume 3: Project-wide effects assessment

Section 5: Ecology – aquatic

List of contents

Page number

List of plates

Page number

List of tables

Page number

This page is intentionally blank

5 Ecology – aquatic

5.1 Introduction

5.1.1 This section presents the findings of the assessment of the likely significant project-wide effects of the proposed development on aquatic ecology.

5.1.2 The proposed development has the potential to affect aquatic ecology receptors throughout the tidal reaches of the River Thames ('Tidal Thames') due to both the physical works in-river during construction and the operation of the Thames Tideway Tunnel project. During operation the interception of each of the combined sewer overflows (CSO) would result in reduced discharges of untreated sewage into the tidal Thames at each location. There would also be permanent in-river structures at the following seven Thames Tideway Tunnel project sites: Putney Embankment Foreshore, Chelsea Embankment Foreshore, Heathwall Pumping Station, Albert Embankment Foreshore, Victoria Embankment Foreshore, Blackfriars Bridge Foreshore and King Edward Memorial Park Foreshore.

5.1.3 The presence of sewage in the aquatic environment has adverse effects on aquatic ecology receptors (habitats, mammals, fish, invertebrates and algae). In particular, discharges of untreated sewage effluent can result in low levels of dissolved oxygen (DO), which can cause mass fish mortalities known as hypoxia events. There are CSOs discharging at locations throughout the tidal Thames.

5.1.4 The tidal Thames comprises a dynamic environment, in which tidal action leads to dispersal of discharges. Therefore the effects of the operational Thames Tideway Tunnel project, which is designed to intercept the most problematic CSOs would be most evident at a project-wide level. These effects are reported in this section. The likely significant effects on aquatic ecology of each of the individual interceptions are dealt with in detail in the site specific volumes (Vols 4 to 27). A project-wide overview of those effects is also provided in this volume.

5.1.5 The assessment of the likely significant effects of the proposed development on aquatic ecology has considered the guidance within the *National Policy Statement for Waste Water*[1] (NPS). In line with this guidance, designations, species and habitats relevant to aquatic ecology are identified and measures incorporated into the proposed development described. Based on assessment findings, measures to address likely significant adverse effects are identified. Vol 2 Section 5 provides further details on the methodology.

5.1.6 Plans of the proposed development as well as figures included in the project-wide assessment are contained in a separate volume (Vol 3 Project-wide effects assessment Figures).

5.2 Proposed development relevant to aquatic ecology

5.2.1 The proposed development is described in Section 3 of this volume, with further details of each site described in Section 3 of Vols 4 to 27. The elements of the proposed development relevant to aquatic ecology receptors are as follows.

Construction

5.2.2 There would be construction works at a total of 24 locations along the main tunnel and connection tunnels. There would be eight sites where temporary cofferdams would be located on the foreshore (ie, Putney Embankment Foreshore, Chelsea Embankment Foreshore, Heathwall Pumping Station, Albert Embankment Foreshore, Victoria Embankment Foreshore, Blackfriars Bridge Foreshore, King Edward Memorial Park Foreshore and Chambers Wharf).

5.2.3 A further three sites (Carnwath Road Riverside, Cremorne Wharf and Kirtling Street) would be used for barging only and would have no temporary cofferdams.

5.2.4 The construction phase is not assessed at sites without in-river works because there is no potential for aquatic ecology impacts and effects.

5.2.5 The location of the sites is illustrated in Vol 3 Figure 5.4.2 to Vol 3 Figure 5.4.4 (see separate volume of figures).

5.2.6 The nature of the construction works at each of the foreshore sites is described in detail in the site specific assessment volumes (Vols 4 to 27). However, for the purposes of the project-wide assessment a summary of the generalised activities which may result in effects on aquatic ecology receptors is provided below.

5.2.7 Establishment of cofferdams at the foreshore construction sites would entail the installation of sheet piles encircling the temporary works areas using equipment such as a jack-up barge. It is assumed for the assessment that the majority of foreshore material within the temporary cofferdams would remain in situ. For structural reasons, soft material located adjacent to the perimeter of the temporary cofferdams and adjacent to the river wall would be removed. The soft material includes silt, peat and other materials. Removal of this material would ensure that any settlement of the cofferdam fill material would not adversely affect the ties between the walls of the twin walled temporary cofferdam leading to structural difficulties. All soft material within permanent cofferdams would be removed to ensure sound foundations for permanent construction.

5.2.8 The exact extent and depth of the foreshore deposits to be removed at each site would be informed by geotechnical investigations. Areas of removed material would be filled with gravel similar to the existing bed material. Details of the approach to the use of fill material at individual foreshore sites are provided in Vol 3 Appendix C.4.

5.2.9 Cofferdam fill material would then be placed onto the foreshore on top of a geotextile layer. Suitable sized plant would be utilised to reduce potential load impacts on the foreshore.

5.2.10 The temporary works areas (excluding the area occupied by the permanent cofferdam) would range in size from approximately 50m^2 at Kirtling Street to approximately 8515m^2 at Albert Embankment Foreshore. In most cases (with the exception of Victoria Embankment Foreshore and Blackfriars Bridge Foreshore, where the intertidal zone is either absent or very narrow) the temporary works area would occupy part of the intertidal zone of the foreshore, and in most cases would extend into the subtidal zone due the size of the site and limited extent of the intertidal zone in some locations.

5.2.11 There would be an area of consolidation and disturbance outside temporary cofferdams and jetties due to operation of a jack-up barge and barge movements.

5.2.12 At all foreshore construction areas barges would be used for moving cofferdam materials in and out. Barging of main tunnel excavated material would be undertaken at Carnwath Road Riverside, Kirtling Street and Chambers Wharf. At most sites where barging would take place a campshed would be constructed on the riverward side of the temporary working area. These would be concrete structures and designed to accommodate barges from 350 tonnes to 1500 tonnes, and range in size from 400m^2 to 3200m^2.

5.2.13 Campsheds would be constructed using a method similar to that described in para. 5.2.7 for the temporary cofferdams. Sheet piles would be used to create the outer edge of the campshed. Soft material would be removed from within the sheet piled area and replaced with a more coarse material similar to the existing river bed in order to provide stability. Concrete would be placed into the sheet piled area on top of a geotextile membrane.

5.2.14 Campsheds are proposed at eight sites namely: Putney Embankment Foreshore, Carnwath Road Riverside, Cremorne Wharf (the existing campshed is to be upgraded or replaced), Chelsea Embankment, Heathwall Pumping Station, Albert Embankment, King Edward Memorial Park Foreshore and Victoria Embankment Foreshore. Campsheds are not required at Kirtling Street, Blackfriars Bridge Foreshore and Chambers Wharf, since barges are mooring in the subtidal zone and are not expected to ‘ground out’.

5.2.15 It has been assumed that dredging to facilitate barge access would generally not be required, although limited dredging would be anticipated at Carnwath Road Riverside, Kirtling Street and associated with the relocated Millennium Pier location at Blackfriars Bridge Foreshore.

5.2.16 The process of decommissioning construction sites would entail the removal of all structures, including campsheds, and temporary cofferdams. Upon removal of the temporary cofferdam, the fill and geotextile layer would be removed and the bed would be reinstated to match the existing river bed conditions. Material excavated would be disposed of in accordance with the project’s waste management procedure. This process is described in further detail in Vol 3 Appendix C.4.

Code of Construction Practice

5.2.17 The *Code of Construction Practice* (*CoCP*)[i] sets out the standards, procedures, and measures for managing and reducing construction effects. These measures would be implemented through a *Construction Environment Management Plan (CEMP)* prepared by the contractor to control site operations and works.

5.2.18 The *CoCP Part A* (see Sections 4, 6, 8 and Section 11) includes the following measures, which are an integral part of the proposed development and relevant for the purposes of this:

a. The location of barges resting on the foreshore and river bed would be controlled to reduce extent of potential environmental impacts. The design of facilities such as campsheds would consider the need to minimise environmental impacts and should consider the use of lattice structure barge grids where appropriate. In-river structures, including campsheds, would be removed on completion of the works unless otherwise agreed. Where concrete is used, such as campsheds, a membrane is required to protect the underlying riverbed. The method for reinstatement of the temporary works area would be subject to a method statement that would consider requirements for impact on aquatic ecology.

b. Avoiding piling at night to ensure free windows of opportunity to allow fish to migrate past the site within each 24-hour period.

c. Undertaking noise measurements at prescribed points and intervals to ensure compliance with the *CoCP*.

d. Limiting allowable noise and vibration levels to leave part of the river cross-section passable at all times.

e. Where technically feasible, utilising low noise/vibration cofferdam or pile/pier installation techniques such as pressing or vibro-piling rather than impact/percussive piling. In the event that in-river percussive piling is needed, prior approval from the Environment Agency (EA) would be required.

f. Where vibro-piling is undertaken, slowly increasing the power of the driving to enable fish to swim away to leave the area before the full power of the pile driver is felt through the river.

g. The contractor shall make every reasonable effort to remove all piles completely from the bed of the river. With the prior written agreement of the Port of London Authority (PLA) the contractor would ensure any piles which prove impossible to fully extract on application of the confirmed minimum crane pull of 40 tonnes, are driven down, cut off or removed to a depth of a least 1 metre below the adjacent riverbed level unless advised otherwise.

h. Dewatering operations for cofferdams and in river structures need to consider fish rescue arrangements. To the extent that it is not dealt

[i] The *Code of Construction Practice (CoCP)* is provided in Vol 1 Appendix A. It contains general requirements (Part A), and site specific requirements for this site (Part B).

with in the Development Consents Order (DCO), prior written consent from the EA is required under the Salmon and Freshwater Fisheries Act, 1975, to net or trap fish, or introduce fish into a water course.

i. Dredging would be undertaken in accordance with any dredging licenses and required permissions from the Marine Management Organisation (MMO) and the EA. So far as is practicable, the critical period of June to August for dredging would be avoided and dredging would be undertaken using techniques that limit the dispersal of intertidal sediments. For example, a back hoe dredger releases less sediment than a trail suction hopper dredger. Where sites that may require dredging lie within the stretch of the river known to support spawning habitat for smelt and dace (ie, Carnwath Road Riverside), due regard would be given to minimise any impact on biodiversity within the river. The restricted period for dredging (ie, June to August) may need to be extended to include the spring period (ie, March to May) at sites (such as Carnwath Road Riverside) lying close to known spawning areas or areas with fresh water riverine species.

j. Avoidance of pollution of the river through measures that accord with the principles set out in industry guidelines, including the EA note PPG05 Works in, near or liable to affect water courses (Environment Agency, undated)[2] and Construction Industry Research and Information Association (CIRIA) report C532: Control of water pollution from construction sites (CIRIA, 2001)[3].

k. Appropriate measures would be taken with regard to 'in river' works to minimise the release of suspended sediment and solids into the water column.

l. For works where materials are being loaded and unloaded on the river, the contractor is required to establish suitable management arrangements and mitigation measures so as to prevent spillage of transferred materials. This includes design of conveyor systems, enclosures, conveyor belt scrapper locations and selection of other loading equipment. Monitoring methods and contingencies arrangements are to be included in the *River transport management plan and Emergency preparedness plan*.

m. In constructing temporary cofferdams the contractor would avoid any mixing of fill material with the underlying substrate. This would be achieved by installing a membrane between the existing river bed and the back fill material.

n. The lighting, to be specified in a *Lighting management plan*, would be designed to comply with relevant standards. This would consider the aquatic environment and avoid direct lighting of watercourses, where reasonably practical, to avoid inhibiting movements of photophobic species such as eel.

Operation

5.2.19 The key elements of the operational phase of the Thames Tideway Tunnel project with relevance to aquatic ecology would be:

a. Discharges from existing CSOs would be intercepted directly as part of the project.

b. Permanent reduction in the volume of untreated effluent discharged from each CSO.

c. Increase in DO concentrations throughout the tidal Thames.

d. Reduction in un-dissociated ammonia concentrations throughout the tidal Thames.

e. Reduction in sewage derived litter.

f. Reduction in sediment.

g. The presence of permanent structures at seven sites in the tidal Thames associated with the CSO drop shafts.

h. Scour protection for the permanent CSO interception structure and discharge apron at each site. This would consist of buried rip-rap which would be overlaid with an appropriate substrate material.

i. The presence of the relocated Millennium Pier and continuation of its use for the movement of vessels. Grounding out of vessels should not occur except occasionally on the lowest tides, since mooring of vessels would be within the subtidal area.

j. Permanent relocation of the Tattershall Castle.

5.2.20 There would be seven permanent structures in the tidal Thames at Putney Embankment Foreshore, Chelsea Embankment Foreshore, Heathwall Pumping Station, Albert Embankment Foreshore, Victoria Embankment Foreshore, Blackfriars Bridge Foreshore, and King Edward Memorial Park Foreshore. They would range in size from approximately 565m^2 (at Putney Embankment Foreshore and Heathwall Pumping Station) to approximately 5250m^2 at Blackfriars Bridge Foreshore. The structures have been designed to minimise loss of foreshore habitat, and are therefore generally a vertical sided structure. The size and shape of the structures have been designed in order to minimise turbulence.

5.2.21 The primary objective of the Thames Tideway Tunnel project is to capture discharges from CSOs into the tidal Thames. This would ensure that the requirements of the *EU Urban Waste Water Treatment Directive (UWWTD)* and the related *UK Urban Waste Water Treatment Regulations (UWWTR)* are met. Should nothing be done to address the current situation, continuing population growth and incremental increases to impermeable areas across London are expected to increase the volume and frequency of discharges to the river. Such increased discharges would have associated increased adverse environmental impacts.

5.2.22 The project is also an important element in ensuring the tidal Thames meets the objectives of the Water Framework Directive (WFD). The *River Basin Management Plan* (RBMP)(Environment Agency, 2009)[4] developed for the tidal Thames as part of the requirements of the WFD, states that the London Tideway Tunnels 'represent the primary measures to address point source pollution from the sewer system and are fundamental to the achievement of good status in this catchment' (Estuaries and Coastal

Waters Catchment). Water quality standards have been developed for the WFD, which water bodies are required to meet in order to attain good status (or good potential). These standards include biological aspects of water quality, and these have been considered in this assessment.

5.2.23 Taking account of the base case (which includes permitted Thames Tideway sewage treatment works upgrades, and the Lee Tunnel scheme) CSO discharges are expected to reduce to 17,600,000 m^3 from the existing 39,668,000 m^3 by 2021. With the Thames Tideway Tunnel project in place discharges would reduce to 2,345,000 m^3.

5.2.24 The reduced discharges would result in a decrease in the occurrence of mass fish mortalities from low DO events (hypoxia) across the tidal Thames and improvements in habitat quality and invertebrate diversity.

Environmental design measures

5.2.25 Generic design principles of relevance to aquatic ecology are as follows (see also *Design Principles* report Section 3 in Vol 1 Appendix B):

a. Where appropriate to context and practicable, fendering (horizontal or vertical) would be included on the permanent foreshore structures, preferably in timber, to promote aquatic ecology.

b. Scour protection would be provided beneath any new outfall extending to below the low water line and along the line of the new river wall (to protect its foundation). The detailed design and extent of this would seek to avoid or minimise adverse effects on aquatic ecology.

c. Where practicable, at the base of the permanent foreshore structures, measures such as low level habitat features would be provided to encourage retention of sediment to promote aquatic ecology and facilitate the passage of fish past the structure.

d. Light pollution would be minimised within the sites by using capped, directional and cowled lighting units. No lighting would be proposed in the water, directed riverward or on the outside of the foreshore structure, unless required for navigational purposes.

5.2.26 At Dormay Street an intertidal terrace would be incorporated into a 36m stretch of the river wall. The terrace would be 2.9m wide and would be situated between the mean low water neaps and the mean high water springs (ie, within the intertidal zone). The terrace would be planted with vegetation characteristic of the marginal habitats that may be expected to occur in the freshwater zone of the river. The terrace represents part of a package of compensation measures designed to offset the effects of permanent landtake on intertidal habitats across all of the Thames Tideway Tunnel project sites. The package of measures is described in further detail in Section 5.8.

5.2.27 At Albert Embankment Foreshore there would be a series of terraces connecting and encircling the interception chamber and the CSO drop shaft structure. The terraces are designed to maximise their biodiversity benefit, and would include at least one vegetated ‘step’ below the mean high water level. The lower terraces would be edged with boulders to provide refuges for fish. The third terrace would be planted with species such as sea aster (*Aster tripolium*), sea clubrush (*Bolboschoenus maritimus),* saltmarsh rush (*Juncus gerardii*), sea plantain (*Plantago maritima*), sea rush (*Juncus maritimus*), reflexed saltmarsh grass (*Puccinellia distans*). Further details of these measures are provided in Section 5.8 and in the site assessment for Albert Embankment Foreshore (Vol 16 Section 5).

5.2.28 At Chelsea Embankment Foreshore there are two design options. One of the options includes vegetated terraces which would be inundated at high tide benefiting aquatic ecology. The other option (floodable public realm) would not include this feature. This project-wide assessment, and the site assessment for Chelsea Embankment Foreshore, considers both options (see Vol 13 Section 5).

5.3 Assessment methodology

5.3.1 The methodology for preparing the project-wide assessment is described in Volume 2 Environmental assessment methodology Section 5. Engagement with stakeholders and methodological assumptions and limitations of specific relevance to the project-wide assessment are detailed below.

Engagement

5.3.2 Vol 2 documents the overall engagement with stakeholders which has been undertaken in preparing the *Environmental Statement*. Vol 2 Section 5.2 describes the approach to stakeholder engagement for the aquatic ecology topic. Specific comments relevant to the assessment of aquatic ecology at the project-wide level are presented in Vol 3 Appendix C.6.

5.3.3 In addition there has been consultation with stakeholders over a wide number of issues, notably the juvenile fish migration modelling and the approach to habitat compensation. The approach to stakeholder engagement in relation to these issues is described below.

5.3.4 In their response to the *Scoping Report* (Thames Water, 2011)[5] the EA highlighted the importance of assessing the cumulative impacts of the construction period, especially in relation to noise and vibration and hydrodynamic impacts. In particular, the impacts of multiple structures during construction and operation on the intertidal foreshore on the migration of fish through the tidal Thames, was raised as a concern. Through their National Encroachment Policy (Environment Agency, undated)[6] the EA is ‘generally opposed to works on tidal rivers and estuaries that cause encroachment’.

5.3.5 A bespoke approach to assessing the effects on juvenile fish of the Thames Tideway Tunnel project temporary and permanent foreshore structures has been developed based on a computer based modelling approach. Details of the approach are presented in paras. 5.5.58 to 5.5.61 and Vol 3 Appendix C.2. The proposed approach was presented to the EA during a meeting in November 2011. The rules which define the way in which fish 'behave' within the model were shared and agreed with the EA with fisheries experts regarding the adequacy of the model to simulate natural fish behaviours within the tidal Thames.

5.3.6 The technical report presenting the findings of the modelling study was sent to the EA and the Port of London Authority for review.

5.3.7 In relation to mitigation and compensation a mitigation hierarchy has been adopted in which impacts are first avoided and minimised where possible. However, residual effects on intertidal and subtidal habitats would be compensated through on and offsite compensation measures. The approach to mitigation and compensation is presented in Section 5.8. At a workshop held in September 2011 members of the Biodiversity Technical Working Group were invited to provide suggestions for potential habitat compensation schemes.

5.3.8 Each of the schemes was reviewed and an assessment of its feasibility undertaken. Information for each of the schemes was stored on a bespoke GIS database. The shortlist of potential schemes was discussed with the EA at a workshop on the 9th November 2011, and progress updates with individual compensation schemes provided at meetings on 29th February and 25th April 2012. The final shortlist of compensation schemes was presented at the final Biodiversity Technical Working Group meeting on 11th July 2012.

5.3.9 In developing the methodology for assessing project-wide effects on aquatic ecology, the EA requested that a balance sheet be applied to understand and document the losses and gains to aquatic ecology. While this has been considered, a balance sheet has not been included. This is because it does not allow a meaningful comparison to be made of the significant qualitative improvements to aquatic ecology resulting from the Thames Tideway Tunnel project compared to the limited permanent loss of foreshore habitat. It has also been agreed with the EA that it is not feasible to achieve a like for like replacement of foreshore habitat, further making a balance sheet approach of limited value. A meeting was held with the EA on 19th December 2012 to discuss the balance sheet and the compensation measures. Section 5.8 sets out the suggested compensation measures to address the loss of foreshore habitat.

Baseline

5.3.10 The baseline methodology follows the methodology described in Vol 2 Section 5. There are no variations for identifying the baseline conditions.

5.3.11 The assessment is based on desk study and survey data. Desk study data has been obtained for the whole of the tidal Thames for habitats, mammals, fish, invertebrates and algae. The data sets for fish, invertebrates and algae are based on fixed sampling locations at intervals through the tidal Thames. Details of the background data sets are provided in Vol 2 Section 5.

5.3.12 Surveys for fish and invertebrates were undertaken during October 2010 and May 2011, within the proposed development site and within 100m radius of the site boundary. During these surveys, the intertidal habitats present were recorded. Surveys for juvenile fish were undertaken at five sampling locations, from Kew to Bermondsey, six times between May and September 2011. Site selection was based on the availability of suitable bed conditions i.e. a firm gravel substrate, suitable water depths and velocities, vicinity to proposed Thames Tideway Tunnel project areas and relative location to other sampled sites. Surveys for algae were undertaken at each of the foreshore sites, in May 2012.

Construction

5.3.13 The assessment methodology for the construction phase follows that described in Vol 2 Section 5. The assessment area extends from the upstream tidal limit at Teddington lock to the limit of the inner estuary as shown in Vol 3 Figure 5.4.1 (see separate volume of figures). It includes the intertidal and subtidal zones of the river.

5.3.14 The assessment year for construction effects is Project Year 1, ie when construction would commence.

5.3.15 Section 5.5 details the likely significant effects on aquatic ecology arising from the construction of the proposed developments at the foreshore sites.

5.3.16 At the project-wide level the construction base case includes the improvements at the five main sewage treatment works that discharge into the tidal Thames (Mogden, Beckton, Crossness, Long Reach and Riverside) and the Lee Tunnel. It has not considered any other schemes listed within the project-wide development schedule (Vol 3 Appendix A.1), as there have been no impacts identified that would lead to effects on the tidal Thames as a whole. The Battersea Power Station development has been considered in terms of potential cumulative effects with nearby Thames Tideway Tunnel project sites, and because these effects apply to more than one Thames Tideway Tunnel project site this is discussed on a project-wide basis in Section 5.7.

5.3.17 As a sensitivity test, the assessment of construction effects also considers the extent to which the assessment findings would be likely to be materially different, should the programme for the Thames Tideway Tunnel project be delayed by approximately one year.

Operation

5.3.18 The assessment methodology for the operation phase follows that described in Vol 2 Section 5. The assessment area is as stated in para. 5.3.13. There are two assessment years for operational effects; Year 1 and Year 6 of operation. Year 1 is the year that the Thames Tideway Tunnel project would be brought into operation. Year 6 provides sufficient time after operation commences to allow the longer term effects on aquatic ecology to be assessed.

5.3.19 Section 5.6 details the likely significant effects arising from the operation.

5.3.20 At the project-wide level the operational base case includes the improvements at the five main sewage treatment works that discharge into the tidal Thames (Mogden, Beckton, Crossness, Long Reach and

Riverside) and the Lee Tunnel. It has not considered any other schemes listed within the development schedule (Vol 3 Appendix A.1), as there have been no impacts identified that would lead to effects on the tidal Thames as a whole. Similarly, there are no schemes that could give rise to cumulative impacts, and therefore no cumulative assessment has been carried out.

5.3.21 As with construction, the assessment of operational effects involves a sensitivity test which considers the extent to which the assessment findings would be likely to be materially different, should the programme for the Thames Tideway Tunnel project be delayed by approximately one year.

Assumptions and limitations

5.3.22 The assumptions and limitations associated with the assessment are presented in Vol 2 Section 5.

Assumptions

5.3.23 It has been assumed that:

a. The area between the outer edge of the temporary foreshore structures such as cofferdams and the maximum extent of working area would be subject to disturbance and consolidation during construction.

b. Loss and disturbance of habitats would be limited to the area within the 'Maximum extent of working area'; and

c. Dredging would only take place at Kirtling Street and Blackfriars Bridge Foreshore.

Limitations

5.3.24 There are no limitations associated with the project-wide assessment of aquatic ecology.

5.4 Baseline conditions

Current baseline

5.4.1 The following section sets out the baseline conditions for aquatic ecology within the assessment area. Future baseline conditions (base case) are also described. In some cases further detail is included in the baseline report (see Vol 3 Appendix C.1).

Water Framework Directive status

5.4.2 The tidal Thames forms part of the Greater Thames Estuary system, which extends from the upper tidal limit at Teddington, down to fully marine conditions below Southend-on-Sea and the Medway. In Water Framework Directive (WFD) terms it is known as a 'transitional water' and is classified as a 'heavily modified water body' (HMWB). This reflects the heavy urbanisation of its shorelines, especially through the City of London. Less than 1% of the original river bank form now remains in place (Colclough *et al*, 2002)[7].

5.4.3 The WFD aims for all water bodies to reach at least 'Good Status (or 'Potential' for HMWB's) by 2015. However, unless certain conditions are satisfied, in some cases the achievement of good status may be delayed until 2021 or 2027. The tidal Thames is divided into three sections for the purposes of the WFD; Thames upper, Thames middle and Thames lower Tideway as follows, and as shown in Vol 3 Figure 5.4.1 (see separate volume of figures)

a. Thames Upper – Teddington to Battersea Bridge;

b. Thames Middle – Battersea Bridge to Mucking Flats; and

c. Thames Lower – Mucking Flats to Southend.

5.4.4 All three sections are currently classified as moderate ecological potential with the aim of reaching good ecological potential by 2027. The current status of biological elements is determined for the Thames middle where invertebrates are listed as 'moderate' and macroalgae as 'high.' Further details of the assessment of water bodies under the WFD are provided in Section 14 of this volume.

Designations and habitats

5.4.5 The tidal Thames is part of the proposed Thames Estuary Marine Conservation Zone (MCZ no. 5) the details of which were submitted to Government in early 2012. If adopted, it will be designated as a national statutory site under the Marine and Coastal Access Act 2009. The purpose of MCZs is to protect the full range of nationally important biodiversity, as well as certain rare and threatened species and habitats. While these are not yet a formal designation, the assessment has nevertheless reviewed the effect of this designation (see Vol 3 Appendix C.5). Species include smelt (*Osmerus eperlanus*), European eel (*Anguilla anguilla*) and tentacled lagoon worm (*Alkmaria romijnii*) (Balanced Seas, 2011) [8]. The tidal Thames offers important spawning and migratory habitat for smelt, and migratory habitat for European eel.

5.4.6 The tidal Thames also includes a number of statutory and non-statutory sites for nature conservation. These are summarised in Vol 3 Table 5.4.1 and Vol 3 Figures 5.4.2 to 5.4.4 (see separate volume of figures).

Vol 3 Table 5.4.1 Aquatic ecology – designated sites

Site name	Borough	Designation	Site description
Thames Estuary and Marshes	Medway, Thurrock, Kent	Special Protection Area (SPA)	The estuary and adjacent grazing marsh areas support an important assemblage of wintering water birds including grebes, geese, ducks and waders. The site is also important in spring and autumn migration periods. To the south of the river, much of the area is brackish grazing marsh. At Cliffe, there are flooded clay and chalk pits and outside the sea wall, there is a small extent of saltmarsh and broad intertidal mud-flats.
Thames Estuary		Marine Conservation Zone (MCZ) (proposed)	The tidal Thames is part of the proposed Thames Estuary Marine Conservation Zone (MCZ no. 5) the details of which were submitted to Government in early 2012. If adopted, it will be designated as a national statutory site under the Marine and Coastal Access Act 2009. The purpose of MCZs is to protect the full range of nationally important biodiversity, as well as certain rare and threatened species and habitats. Species include smelt (Osmerus eperlanus), European eel (Anguilla anguilla) and tentacled lagoon worm (Alkmaria romijnii) (Balanced Seas, 2011) [9].
Inner Thames Marshes	Havering, Thurrock	Site of Special Scientific Interest (SSSI)	The largest remaining expanse of wetland bordering the upper reaches of the Thames Estuary that supports a variety of breeding birds and the numbers of wintering wildfowl, waders, finches and birds of prey, with wintering teal populations reach levels of international importance. The Marshes also support a wide range of wetland plants and insects with a restricted distribution in the London area, including some that are nationally rare or scarce.
Syon Park	Hounslow	SSSI	The only known area of tall grass washland along the Thames in Greater London; it contains several invertebrate species with a restricted distribution, both locally and nationally.
Barn Elms Wetland Centre	Richmond upon Thames	SSSI	A mosaic of different wetland habitats created on the site of redundant artificial reservoir basins comprising areas of standing open water, grazing marsh and reedbed.

Site name	Borough	Designation	Site description
Dukes Hollow	Isleworth	Local Nature Reserve (LNR)	A small area of ecological importance by Barnes Bridge on the tidal Thames with a natural tidal foreshore, featuring a variety of waterside plants and two nationally rare snails: the Two Lipped Door Snail and the German Hairy Snail.
Leg of Mutton Reservoir	Richmond upon Thames	LNR	The reservoir supports breeding birds including grey herons and kestrels. The higher levels of past years are marked by lines of fresh-water mussel shell deposits on the inner slopes. It contains the rare and declining species the native black poplar. Eleven species of mammals have also been recorded, including the declining water vole and three species of bat. The scarce and protected great crested newt is also present.
Isleworth Ait/Ayot	Hounslow	LNR	A small island within the channel of the tidal Thames. The key habitats present are wet woodland and rivers and streams. It is these habitats that encourage the populations of birds, Red Data Book (very rare) mollusc species such as the Silky Snail (Perforatella rubiginosa) and important beetle species.
Chiswick Ayot	Hounslow	LNR	A small island within the channel of the tidal Thames. The island is covered with low-growing willow pollards and supports wetland flora and provides nesting habitat for waterfowl.
Lavender Pond	Southwark	LNR	Comprising a pond and reedbeds, this is managed as an education centre and supports a population of damselflies.
River Thames and Tidal Tributaries	All	Site of Importance for Nature Conservation (Grade III of Metropolitan importance) The tidal Thames is also part of the Thames Estuary	The River Thames supports a diverse mix of habitats, including open water, intertidal mud, sand, shingle and small areas of relatively poor saltmarsh. The SINC is particularly important for a range of bird and fish species, including common tern (*Sterna hirundo*), reed warbler (*Acrocephalus scirpaceus*) grey heron (*Ardea cinerea*) and teal (*Anas crecca*) bass (*Dicentrarchus labrax*), eel (*Anguilla anguilla*) and flounder (*Platichthys flesus*).

Site name	Borough	Designation	Site description
		Marine Conservation Zone that was submitted to government in early 2012.	
Beverley Brook	Kingston upon Thames, Richmond upon Thames, Wandsworth, Merton and Sutton	Site of Importance for Nature Conservation (SINC Grade B (of Borough importance))	Beverly Brook rises from the Southern edge of the London Clay basin between Stoneleigh and Sutton in Surrey and flows into the tidal Thames at Barn Elms. Its main tributaries are Pyl Brook, East Pyl Brook and Coombe Brook. The brook flows through numerous designated sites including Fishpond Wood and Beverley Meads LNR, Coombe Wood LNR, Richmond Park National Nature Reserve (NNR) and Barns Common LNR.

5.4.7 The UK signed up to the international Convention on Biological Diversity (CBD) in 1992. The CBD called for the development and enforcement of national biodiversity strategies and action plans, to identify, conserve and protect existing biological diversity, and to enhance it wherever possible. The resultant UK Biodiversity Action Plan (UK BAP) was created in 1994, and represents the UK Government's response to the CBD. The UK BAP outlined the UK's biological resources and provided detailed plans for conservation of these resources (Joint Nature Conservation Committee, undated)[10].

5.4.8 The UK BAP is implemented at regional and local level through local BAPs and for specific habitats within these, tailored Habitat Action Plans (HAPs). The tidal Thames is the subject of a HAP within the London BAP (Thames Estuary Partnership Biodiversity Action Group, undated)[11], and the targets prescribed for this HAP are reflected in more local (Borough-level) BAPs, where they exist. The tidal Thames HAP identifies a number of habitats and species which characterise the estuary, such as gravel foreshore, mudflat and saltmarsh. A number of these habitats and species, including mudflat, are also the subject of action plans under the UK BAP.

5.4.9 The *Tidal Thames Habitat Action Plan* (Thames Estuary Partnership Biodiversity Action Group, undated) [12] identifies three zones of the tidal Thames, based on salinity levels; freshwater, brackish and marine. This is illustrated in Vol 3 Figure 5.4.1 (see separate volume of figures).

5.4.10 There are no standard techniques for surveying intertidal and subtidal habitats. The distribution of habitats has been recorded at the sample sites visited for fish and invertebrate surveys in autumn 2010 and spring 2011. The approach to recording habitats for the purposes of this assessment is described in Vol 2 Section 5. In summary, habitat types, substrate composition and any vegetation communities associated with the foreshore or river wall were recorded and mapped at each of the proposed foreshore construction sites.

5.4.11 A range of intertidal and subtidal habitats were recorded including gravel foreshore, mudflats and subtidal sands and gravels across the sites. Broadly, habitats are more diverse upstream of Chelsea, with large gravel foreshores below the river walls, which are exposed at low tide in sites between Hammersmith and Wandsworth. Habitats present are shown in Vol 3 Table 5.4.2.

5.4.12 Many of these upstream sites have trees and other marginal vegetation on and above the river wall. This is most notable at upstream sites such as Hammersmith Pumping Station, Putney Embankment Foreshore and Barn Elms.

5.4.13 Through central London, the tidal Thames is more constrained within the river walls, and the intertidal habitat is narrow and consists of more homogenous sand and gravel. At sites such as Victoria Embankment Foreshore, Albert Embankment Foreshore and Blackfriars Bridge Foreshore, intertidal habitat is limited to small areas of gravel in limited areas near to the river wall. However, at low water on the spring tide, it is likely that larger areas may occasionally be exposed.

5.4.14 The watercourse is confined within a constructed river wall throughout the area surveyed. The wall is vertical at most of the sites, with exception of some upstream areas including the sample site at Barn Elms, where the wall is sloping.

5.4.15 The wall provides habitat for some limited vegetation and algae. Significant algal growth was noted at some sites, including Putney Embankment Foreshore. In addition, there are a number of structures (such as wooden piers) that provide a habitat for algae and other organisms. However, there were very few areas where macrophytes or macro-algae were recorded in the subtidal or intertidal areas other than the tidal wall (for example on the gravel foreshore).

5.4.16 There is a range of different substrate present in the intertidal areas, including sand, silt, shingle, pebbles and cobbles. However, most of the intertidal areas are dominated by shingle and pebble sized media. There is some finer material (silt and sand) in areas near to outfalls, tributaries and dock outlets. Likewise, substrate in subtidal areas that were sampled included sand, silt, shingle, pebbles and cobbles (based on airlift samples only). However, further into the estuary it is likely that this fine sediment becomes more dominant in both intertidal and subtidal zones.

5.4.17 Of note at Cremorne Wharf Depot there is an area described by the EA as a mudflat unit where Chelsea Creek discharges into the tidal Thames. These mudflats extend from the creek mouth downstream to Cremorne Wharf Depot and beyond. Chelsea Creek, which is identified as a ‘flagship site’ for its range of intertidal habitats, discharges approximately 50 m upstream (west) of Cremorne Wharf Depot.

5.4.18 In addition to the main tidal Thames, there are a number of tributaries and tidal creeks within the study area. These include Deptford Creek, Chelsea Creek, the River Lea (and its tributaries) and Bell Lane Creek. The tidal creeks are known to be important areas for fish.

Vol 3 Table 5.4.2 Aquatic ecology – intertidal and subtidal habitats at foreshore sites

Foreshore site	UK BAP target habitats present and features of interest	Substrate present in intertidal zone (approximate cover)	Substrate present in subtidal samples
Putney Embankment Foreshore	Gravel foreshore Sublittoral sand and gravels River wall Pier (Putney Pier)	Pebbles and shingles (85%) Sand, cobbles, silt (15%)	Pebbles Gravel Sand
Dormay Street	Gravel foreshore Silty, exposed areas Sublittoral sand and gravels Mudflats River wall	Pebbles (20%) Silt (55%) Cobbles (10%) Shingle (15%)	Thick mud overlying gravel
Carnwath Road Riverside (subtidal habitats determined for opposite bank only during autumn 2010*)	Gravel foreshore Sublittoral sand and gravels River wall	Pebbles (45%) Sand and silt (20%) Shingle (20%) Cobbles (15%)	Pebbles Gravel Sand
Cremorne Wharf Depot	Gravel foreshore Sublittoral sand and gravels River wall Tidal Creek Mudflats Wooden pier	Pebbles (35%) Silt (35%) Shingle, sand, cobbles (30%)	Shingle, pebbles, sand
Chelsea Embankment Foreshore	Gravel foreshore Sublittoral sand and gravels River wall Mudflats	Pebbles (50%) Shingle (20%) Sand (15%) Silt (15%)	Sand, gravel, pebbles, hard bottom
Kirtling Street	Gravel foreshore	Pebbles (70%)	Sand

Foreshore site	UK BAP target habitats present and features of interest	Substrate present in intertidal zone (approximate cover)	Substrate present in subtidal samples
	Sublittoral sand and gravels River wall Mudflats	Silt (15%) Sand, cobbles (15%)	Silt Gravel
Heathwall Pumping Station	Gravel foreshore Sublittoral sand and gravels River wall, Mudflats	Pebbles (70%) Silt (15%) Sand, cobbles (15%)	Sand Silt Gravel
Albert Embankment Foreshore	Gravel foreshore Sublittoral sand and gravels, River wall	Pebbles (75%) Shingle (15%) Sand (10%)	Pebbles Gravel Sand
Victoria Embankment Foreshore	Gravel foreshore Sublittoral sand and gravels, River wall Mudflats	Sand (40%) Silt (40%) Shingle, pebbles (20%)	Sand Gravel Some pebbles
Blackfriars Bridge Foreshore	Gravel foreshore Sublittoral sand and gravels River wall, Mudflats	Pebbles (50%) Cobbles (30%) Sand, silt (20%)	Pebbles Gravel Sand
Chambers Wharf	Gravel foreshore Sublittoral sand and gravels River wall	Pebbles (60%) Cobbles (20%) Sand, silt (20%)	Not determined**.
King Edward Memorial Park Foreshore	Gravel foreshore Sublittoral sand and gravels River wall Mudflats	Cobbles (50%) Pebbles (30%) Sand (20%)	Pebble Gravel Sand

**Subtidal habitats were determined from the opposite bank of the river, as the 2010 survey was undertaken at the location of the alternative site Hurlingham Wharf. However the subtidal substrate sample is considered to be representative of this stretch of the river.*
*** The composition of subtidal sediment for most sites was determined through substrate collected by the suction sampler used to collect subtidal invertebrates. In the case of Chambers Wharf, insufficient substrate was collected to make a judgement.*

Habitat evaluation

5.4.19 The intertidal and subtidal habitats of the tidal Thames are considered to be of medium-high (Metropolitan) importance to due to presence of species and habitats listed on the national and regional BAP.

Mammals

5.4.20 Information regarding cetaceans and other marine mammals has been obtained from three sources; Zoological Society of London (ZSL), British Divers Marine Life Rescue and Essex Biodiversity Partnership. Data is available for the past ten years and includes anecdotal records of whales, dolphins, porpoises and seals throughout the tidal Thames. This is presented in Vol 3 Figure 5.4.5 to Vol 3 Figure 5.4.8 (see separate volume of figures).

5.4.21 The tidal Thames is visited from time to time by several species of whales, dolphins, and porpoises and pinnipeds (seals). They may feed on fish during their visits. They are highly valued by the public and may be seen as a demonstration of good quality water.

5.4.22 Between 2003 and 2011 a total of 87 common seal (*Phoca vitulina)* sightings were recorded in the ZSL database (mainly individual sightings but occasionally groups of two or more), 91 grey seal (*Halichoerus grypus*) sightings were recorded (mainly individuals) and 83 harbour porpoise (*Phocoena phocoena*) sightings were recorded (mainly individuals but occasionally groups of three to six). There were also three records of bottlenose dolphin (*Tursiops truncatus*) (although none since 2006) and a single record of a pod of three pilot whales (*Globicephala melas*) in 2006.

5.4.23 The sightings were spread along the entire length of the tidal Thames from Richmond to Southend (with a greater density of sightings between Westminster and Greenwich. Seal sightings (both grey and common) were particularly concentrated around the Isle of Dogs where they are known to enter the complex of docks. The EA has highlighted the importance of undisturbed shorelines such as Chiswick Eyot as a haul out area for grey seals. Although there is no concentration of records for this site, common, grey seal and harbour porpoise have been recorded in the vicinity. ZSL believe that these visits are usually made by inquisitive young and not by populations settling in the tidal Thames.

5.4.24 Mammals are considered to be of high (regional) importance due to the diversity of marine mammal species represented within the tidal Thames.

Fish

5.4.25 This section presents a summary of the baseline information relating to fish within the assessment area. The available fisheries baseline data consists of long-term spring and autumn EA sampling programme from a range of tidal Thames sites; and data collected specifically for the Thames Tideway Tunnel project. Baseline fish surveys were undertaken during October 2010 and May 2011 at Thames Tideway Tunnel project foreshore sites. A further suite of surveys targeting juvenile fish within the shallow margins of the river were undertaken between May and September 2011.

5.4.26 This section aims to present an overview of the fish community in terms of its composition and the distribution of species, as well as highlighting the functional importance of the tidal Thames as a habitat for feeding, spawning and migration. Where possible, any trends in the composition of the fish community over time are highlighted based on the EA background dataset. Raw data and more detailed analysis is provided in the *Thames Tideway Tunnel Aquatic Ecology Baseline Report* (Vol 3 Appendix C.1). The following section focuses on four main areas:

a. an overview of fish community composition and its change with distance through the tidal Thames ;

b. the presence of rare and notable species;

c. the function of the tidal Thames as a migratory route;

d. the nature and range of notable habitats for fish through the tidal Thames, including spawning and nursery habitat.

Overview of fish community composition

5.4.27 The tidal Thames section from Teddington to Greenwich has a complex and dynamic fish community comprised of a wide range of species, from euryhaline salmonids (wide salt-tolerance), eel, flounder and bass to freshwater cyprinids, perch (*Perca fluviatilis*), zander (*Sander lucioperca*) and pike (*Esox lucius*). The distribution of individual species fluctuates naturally through the seasons as fish move between spawning, nursery and adult feeding areas, but is also affected by shifting salinity contours, water quality factors and pollution events.

5.4.28 Fish in the tidal Thames can be classified according to their ecological guilds, which describe the nature of their estuarine occupancy. A simple guild classification (Elliott and Taylor, 1989)[13] is presented in Vol 3 Table 5.4.3.

Vol 3 Table 5.4.3 Aquatic ecology – ecological fish guilds and water body use

Ecological guild (abbreviated form)	Use of water body
Estuarine residents (ER)	Spend whole life in transitional water; e.g. gobies (Pomatoschistus spp), flounder (*Platichthys flesus*), sand-smelt (*Atherina presbyter*).
Marine seasonal (MS)	Marine species with seasonal migrations to transitional water as adults; eg, John Dory (Zeus faber), greater weever (*Trachinus draco*), thornback ray (*Raja clavata*).
Marine juvenile (MJ)	Marine species using transitional water as a nursery area; e.g.: Dover sole (*Solea solea*), bass (*Dicentrarchus labrax*).
Diadromous species (CA)	Species that use transitional waters during migrations between marine and freshwater habitats; eg, eel (*Anguilla anguilla*), river and sea lamprey (*Lampetra flluviatilis*; *Petromyzon marinus*), salmon (*Salmo salar*), sea trout

Ecological guild (abbreviated form)	Use of water body
	(*Salmo trutta*); smelt (*Osmerus eperlanus*), Twaite shad (*Alosa fallax*).
Adventitious marine species (MA)	Marine species with no transitional water requirement ; eg, herring (*Clupea harengus*), sprat (*Sprattus sprattus*)
Adventitious freshwater species (FW)	Freshwater species with no transitional water requirement; eg, common bream (*Abramis brama)*; dace (*Leuciscus leuciscus*)

Thames Upper

5.4.29 In the Upper Tideway, above Battersea, the fish community is dominated by adventitious freshwater species, predominantly dace, with roach, perch, and common bream sub-dominant. However, estuarine resident and diadromous species such as smelt, sand-smelt, bass (*Dicentrarchus labrax)*, *flounder* and *gobies (*common and sand, *Pomatoschistus microps* and *Pomatoschistus minutus.)*, are also common in the Upper Tidal Thames as far upstream as Richmond by the later summer months, having made their way from the Lower Tidal Thames or sea.

Thames Tideway Tunnel baseline surveys (Oct 2010 and May 2011)

5.4.30 During the Oct*ober 2010 surv*eys, spatial peaks in the abundance and diversity of freshwater species were recorded at upstream sites, notably Barn Elms. The site at Barn Elms stands out as having by far the greatest range and numbers of fish species recorded by comparison with all other sites. In particular, the freshwater species roach and bream were most numerous.

5.4.31 In the October 2010 survey, smelt represented the most abundant round-fish species recorded in the samples and showed greatest densities in the 2-3 km of river between Chelsea Embankment Foreshore and Cremorne Wharf Depot. Common goby showed a rather similar pattern, but with the peak numbers recorded marginally further upstream than smelt, between Putney Embankment Foreshore and Chelsea Embankment Foreshore.

5.4.32 Fish numbers were altogether lower in the May 2011 samples than in October 2010. Roach were the most abundant species recorded in the survey. The absence of older fish from the catches may suggest that mature fish have moved into more stable upstream freshwater areas in preparation for spawning. The largest aggregations of roach were observed at Kirtling Street, probably due to the cover offered by numerous boat moorings at this site. Bream were also caught at sites where roach were present but always in lower numbers. The bream population also showed a similar age structure to the roach population. Numbers of 0-group flounder (2011 fry) were caught from three sites between Putney Embankment Foreshore and Chelsea Bridge. The very small size of these flounder indicates that the spring sampling period coincided with the initial phase of juvenile flounder migration into the tidal Thames.

5.4.33 Only small numbers of smelt were caught in the spring 2011 survey, significantly less than the numbers recorded in the autumn survey. It appears that by the time of sampling in spring 2011 smelt had already spawned and adults returned to the lower estuary. Due to the timing of the 2011 survey, it was not possible to assess the potential for smelt spawning at any of the sampled sites. However, as fry-stage fish were caught at Kew, an area further up-stream than any of the sites sampled in the survey, it appears likely that the 2011 smelt spawning took place somewhere towards the tidal limit, near Richmond. This would be consistent with the findings of other reports which suggest Thames smelt spawn in the area upstream of Battersea (Colclough *et al.*, 2002).

Thames Middle

5.4.34 The fish community of the mid-tidal Thames is recorded in the relatively long-term EA fisheries survey data set for Greenwich (1992 to 2011), and at the upstream limit by data for Battersea (1993-2011). Examination of the raw data shows that species presence has remained relatively consistent, with various age classes of bream, dace, roach, bass, flounder (see Vol 3 Plate 5.4.1), smelt, thin-lipped grey mullet (*Liza ramada*) and eels. This suggests that the community in the mid-tidal Thames is relatively stable, and influenced most strongly by salinity and factors other than water quality. The tidal Thames Middle fish community can be characterised as being composed of mixed cyprinid species of a range of ages (bream, roach and dace) in addition to juveniles of more euryhaline species. These juveniles arise from spawning either within the estuary (smelt), at sea (flounder, bass, eel), or from a range throughout the Thames estuary (grey mullets).

Vol 3 Plate 5.4.1 Aquatic ecology − juvenile flounder caught during baseline surveys in May 2011

5.4.35 In the review of the fish community of the Middle to Lower Tideway during the 1980s (Araujo *et al*, 2000)[14] it was concluded that, at that time, the lower reaches of the Thames Middle section (around the West Thurrock Power Station) was dominated by seasonal peaks of fish abundance as follows:

a. December-March - Marine species such as herring (*Clupea harengus)*, sprat (*Sprattus sprattus)*, 3-spined stickleback (*Gasterosteus aculeatus)*, and poor cod (*Trisopterus minutus)*;

b. July-August : flounder; and

c. September-December: sand goby (*Pomatoschistus minutus)*, whiting (*Merlangius merlangus)*, bass, plaice (*Pleuronectes platessa)*, and dab (*Limanda limanda)*.

5.4.36 Dover sole (*Solea solea)*, Nilsson's pipefish (*Sygnathus rostellatus)* and pouting (*Trisopterus luscus)* had variable peaks in abundance as did smelt and eel. The study identified that the environmental variables that had the strongest association with fish abundance (across species) were temperature and DO concentration.

Thames Lower

5.4.37 The Thames Lower extends downstream of Mucking to the outer estuary. The Thames Lower section is important within the whole lifecycle of many species.

Rare and notable species

5.4.38 A number of the fish species which occur within the tidal Thames are protected under national and international legislation. A summary of their protected status and occurrence within the tidal Thames is provided in Vol 3 Table 5.4.4 .

Vol 3 Table 5.4.4 Aquatic ecology – rare and notable fish species

Species	Importance	Occurrence	Comments
Dover sole *Solea solea*	UKBAP priority species	Middle and lower tidal Thames/transitional water. The Thames estuary is one of the most important nursery grounds for Dover sole in the UK.	There are five main spawning areas in the southern North Sea, with nursery areas in shallow waters all along the coasts, although their relative contributions from year to year are variable (Beek *et al*, 1989)[15]. The Thames estuary is recognised as one of the largest east coast nurseries (Thomas, 1998)[16]
Twaite shad *Alosa fallax*	Annex II and V of EC Habitats directive, Appendix III of the Bern Convention and in Schedule 5 of the Wildlife and Countryside Act 1981 UKBAP priority species	Middle and lower tidal Thames. Occurs predominantly downstream of W.Thurrock (Colclough *et al*, 2002)[17]. Common around Mucking Flats and have been present in power station intake catches at Tilbury and West Thurrock (JNCC, undated)[18]. Not known to breed in the Thames.	Young twaite shad of 16-21cm in length have been caught in the Thames in recent years, which is a sign of improving water quality though not a sign of breeding in the tidal Thames.
Allis shad *Alosa alosa*	Annex II and V of EC Habitats Directive Appendix III of the Bern Convention	Middle and lower tidal Thames. Has been recorded in the River Thames estuary, but does not breed (Colclough, 2001)[19].	DO levels are likely to be restricting both species of shad from migrating upstream. If they were able to migrate into the Upper Tideway, other factors may be limiting, including the lack of suitable spawning habitat and, in the case of Allis shad, lack of suitable fish passes to enable them to spawn in more suitable areas upstream of Teddington Lock.
Smelt *Osmerus eperlanus*	Estuarine SCC in the tidal Thames Local Biodiversity Action Plan (LBAP)	Whole tideway. Present in the tidal Thames in increasing numbers in recent years and spawn near Wandsworth.	Species very sensitive to low DO. Surveys have shown that missing juvenile year classes can occur following major CSO

Species	Importance	Occurrence	Comments
			pollution events.
Sea lamprey *Petromyzon marinus*	Annex II of Habitats Directive Appendix III of the Bern Convention[20]	Transitional waters. Migrate through Thames Estuary to reach freshwater habitats and is increasing its appearance in the tidal Thames due to improved water quality. Spawning may take place downstream of Teddington.	Tidal Thames has seen increasing returns of sea lamprey.
River lamprey *Lampetra fluviatilis*	Annex II and V of the Habitats Directive Appendix III of Bern Convention	Whole tidal Thames. Migrate through Thames Estuary to reach freshwater habitats.	Tidal Thames has seen increasing returns of river lamprey.
Atlantic salmon *Salmo salar*	Annexe II of Habitats Directive. Salmon & Freshwater Fisheries Act (1975) Salmon Act (1986)	Whole tidal Thames. Adults migrate through Thames Estuary from spring to autumn to reach freshwater habitats. Smolts descend tidal Thames in spring to reach the sea.	Salmon found in the tidal Thames are mainly strays from other south-coast stocks or from Environment Agency stocking of early life stages. Adult returns have declined to single figures in recent years and EA have ceased stocking.
European eel *Anguilla anguilla*	The Eels (England & Wales) Regulations (2010) UKBAP Priority Species Species of principal importance for the purpose of conservation of biodiversity under the Natural Environment and Rural Communities Act 2006 Critically Endangered on the IUCN Red List	Whole tidal Thames Glass eels/elvers migrate through Thames Estuary from spring to summer to reach freshwater habitats, many remaining in the tidal Thames. Silver eels descend the tidal Thames in autumn to reach the sea.	European eel stocks in the UK have declined to <5% of their numbers up to the 1970s (Natural England, 2012)[21].

Species	Importance	Occurrence	Comments
Short snouted seahorse *Hippocampus hippocampus*	Schedule 5 of the Wildlife and Countryside Act 1981 UKBAP priority species UKBAP Priority Species Natural Environment and Rural Communities Act 2006 Annex II of CITES	Short snouted seahorses are found in the extreme south of England and the Channel Islands. Individuals have been recorded within the tidal Thames.	Presence of short snouted seahorse in the tidal Thames is a sign of improving water quality.

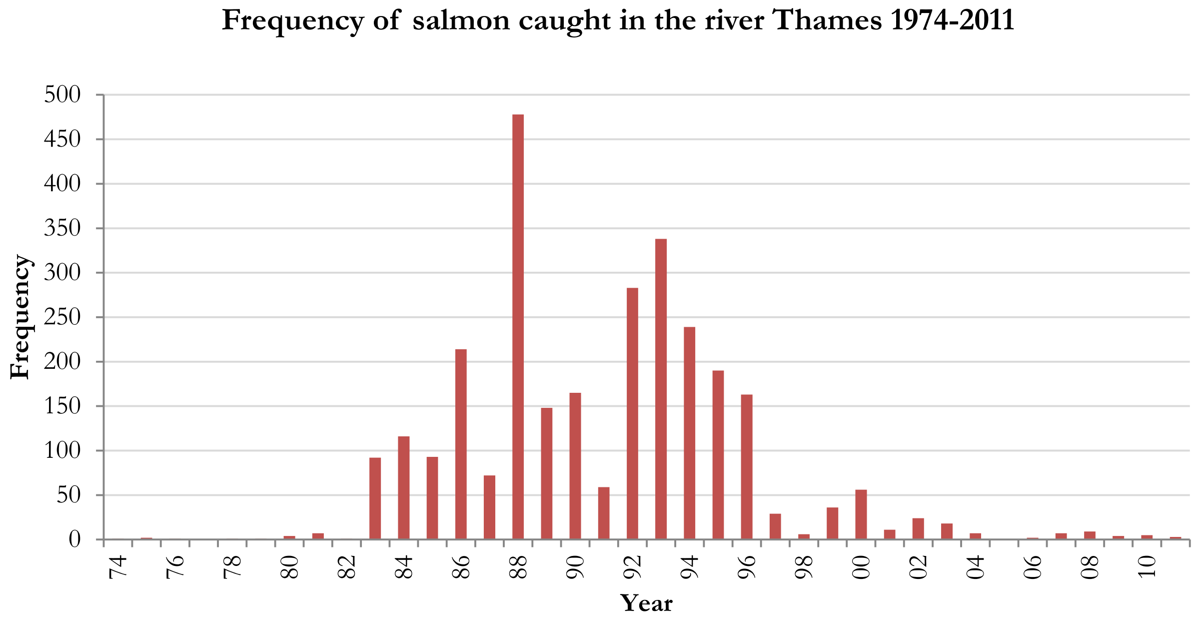
5.4.39 As well as notable species of conservation importance, small numbers of juveniles (one or two per survey) of the non-indigenous zander were caught on three occasions during juvenile surveys.

Fish migrations

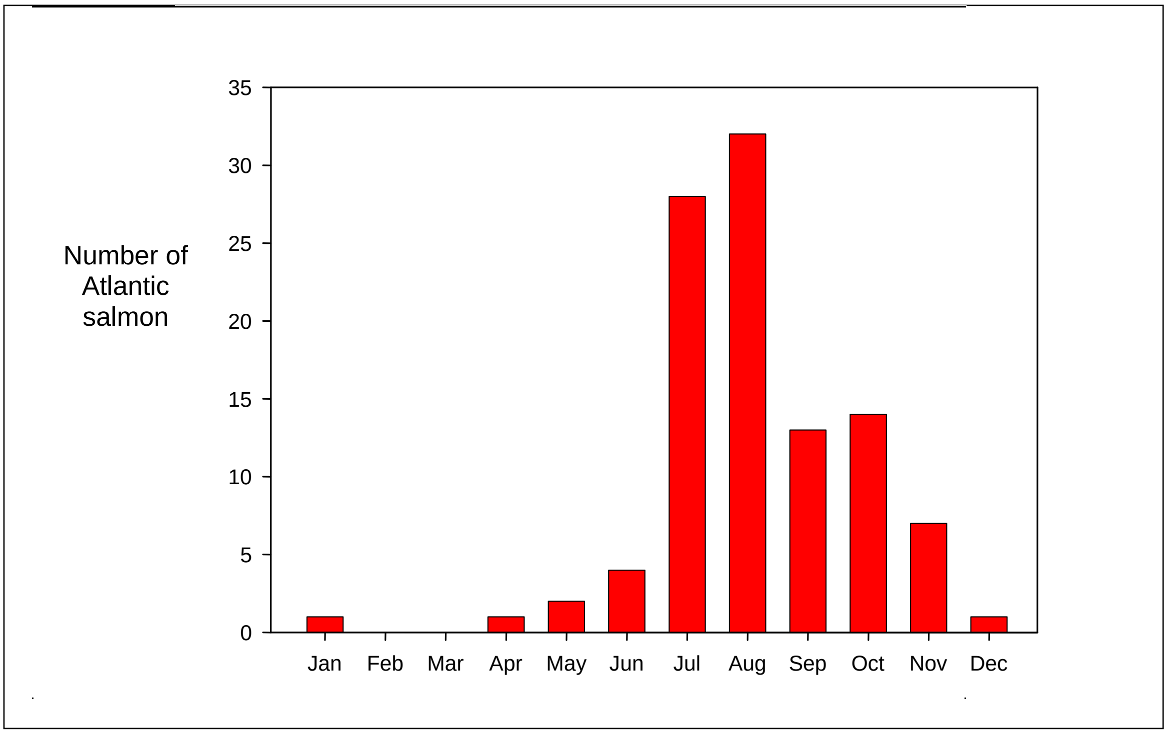
5.4.40 The tidal Thames represents an important migratory route for a number of freshwater adventitious, estuarine resident and diadromous species. The Atlantic salmon is an anadromous species, meaning that it spawns in freshwater with the young moving downstream to the sea as smolts after one or two years in the river.

5.4.41 The EA monitor salmon and sea trout migrations in the tidal Thames and annual adult catch records are available, based mainly on fish trap data from Molesey and Sunbury weirs, with occasional rod and electrofishing catches. The regular run of salmon, as indicated by counts of returning individuals (Vol 3 Plate 5.4.2), averaged about 200 fish per year between 1986 and 1995, peaking at 338 fish in 1993, but the numbers have been low in more recent years, with zero recorded in 2005 and four, five and ten respectively recorded in the years 2009, 2010 and 2011. Poor estuarine water quality in the tidal Thames during the critical summer months, coupled with low summer freshwater input has been considered a major factor (Griffiths *et al*, 2011)[22], The seasonal pattern of returns over the more abundant (Vol 3 Plate 5.4.3) years shows that July and August have been the most active months for salmon returns.

Vol 3 Plate 5.4.2 Aquatic ecology – frequency of salmon caught in the tidal Thames between 1974 and 2011



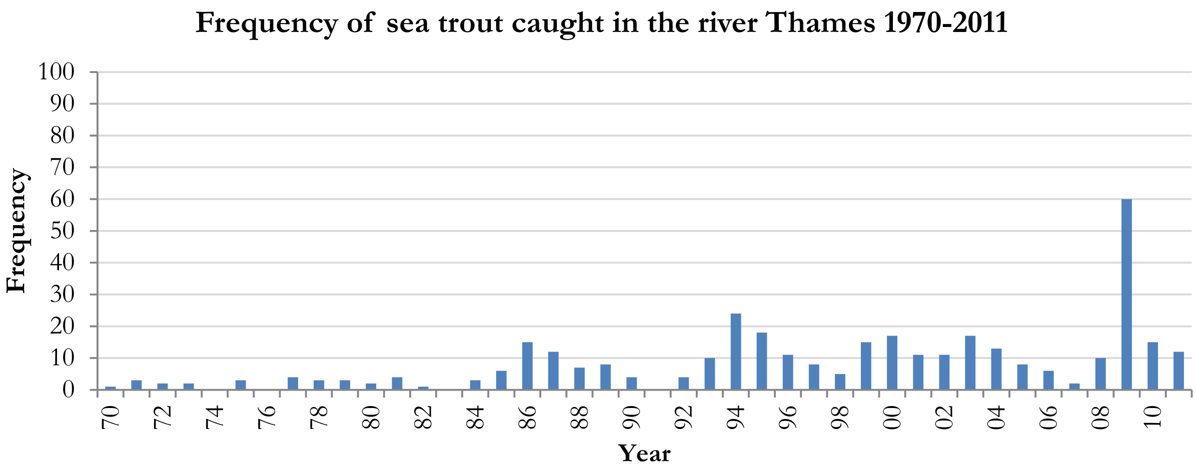
Vol 3 Plate 5.4.3 Aquatic ecology – monthly distribution of salmon returns to the tidal Thames



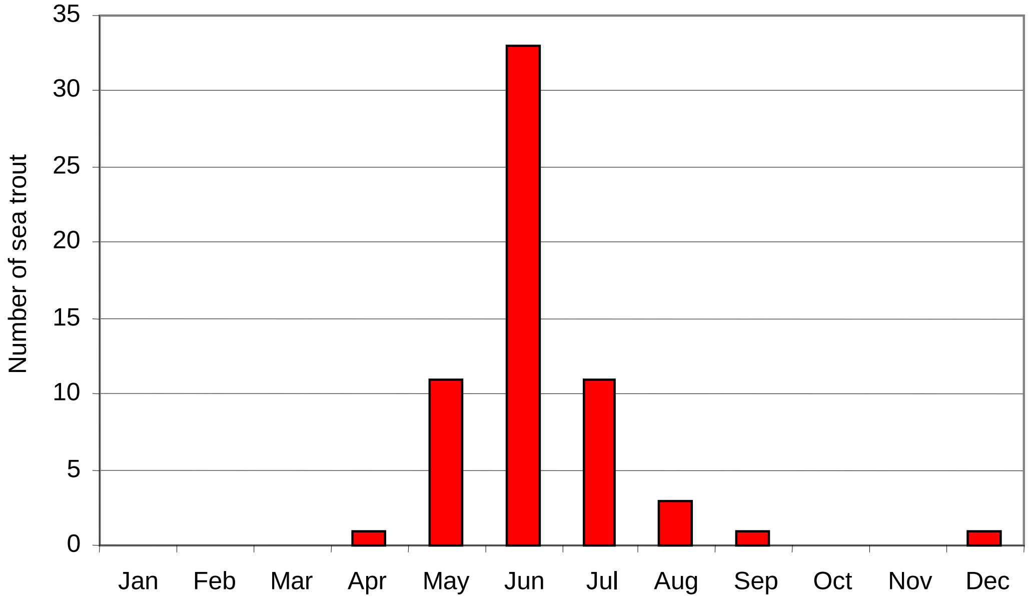
Note: based on EA data for the 20 years to 2001

5.4.42 Sea trout returns have generally been rather lower than those for salmon, totalling less than five per year from 1970 to the mid-1980s (Vol 3 Plate 5.4.4). Returns have averaged around ten per year since that time, and peaked at 60 in 2009. Runs peak a little earlier in the year than salmon (Vol 3 Plate 5.4.5), such that peak sea trout migrations avoid the highest summer temperatures and are less likely to be affected by DO sags in the tidal Thames.

Vol 3 Plate 5.4.4 Aquatic ecology – frequency of sea trout caught in the tidal Thames 1970 to 2011



Vol 3 Plate 5.4.5 Aquatic ecology – monthly distribution of sea trout returns to the Thames



Note: based on five years of data between 2001 and 2005

5.4.43 Other known tidal Thames fish migrations are summarised below in Vol 3 Table 5.4.5. Further details on these migratory movements are provided in the literature review provided in Vol 2 Appendix C, Vol 2 Annex B.

Vol 3 Table 5.4.5 Aquatic ecology – spawning and dispersal movements of non-salmonid fish in the tidal Thames (Colclough *et al*., 2002)[23].

Species	Observed behaviour
Smelt	Adult migration upstream from below Gravesend to spawn above Battersea in March and April.
Dace	Adults mass to spawn in the Wandsworth area in April.
Sand-smelt	Adults spawn in the Greenwich area in June.
Sole	Adults spawn below Gravesend / Tilbury in April/May.
Eel	Glass eel arrive in the estuary in early April and spread upstream through the tidal Thames and into freshwater over the course of the summer.
Flounder	Larvae and metamorphosed juveniles move up the estuary, using tidal stream transport in April/May
Common goby	Fry appear in June

Species	Observed behaviour
Bass	Waves of bass fry arrive from offshore spawning areas in June, July and August.
Thin-lipped grey mullet	Fry enter the tidal Thames in September.

Juvenile fish migrations and fish nursery areas in the Middle and Upper Tideway

5.4.44 Juvenile fish migrations make use of the lower-velocity shorelines where, during the summer months, concentrations of small fish can often be seen in the shallow margins, eddies and bays and behind the shelter of structures such as bridge supports, jetties, marginal macrophyte beds, etc[24]. Such sheltered habitats are vital for the survival of young weakly-swimming fry of many fish species. Observations made during the present study indicate that a gradually-sloping intertidal foreshore, such as that found at Putney Embankment Foreshore (Vol 3 Plate 5.4.6), and shallow backwater areas, are a preferred condition, with consistently high overall juvenile fish biodiversity and abundance in such areas. Shallowly-sloping shorelines allow juvenile fish to remain in the relative safety of shallow, slower-moving water, throughout the tidal cycle.

Vol 3 Plate 5.4.6 Aquatic ecology − Seine netting a shallow embayment on Putney Embankment Foreshore (May 2011)

5.4.45 Juvenile fish surveys were undertaken in 2011 in order to inform modelling of the hydraulic effects on Thames Tideway Tunnel project structures on juvenile fish migrations. These are fully detailed in the aquatic ecology baseline report (Vol 3 Appendix C.1) and their significance to understanding juvenile migrations in the tidal Thames within the Juvenile fish migration modelling report (Vol 3 Appendix C.2). They are considered here as they provide additional baseline information.

5.4.46 The juvenile surveys provide the following key data:

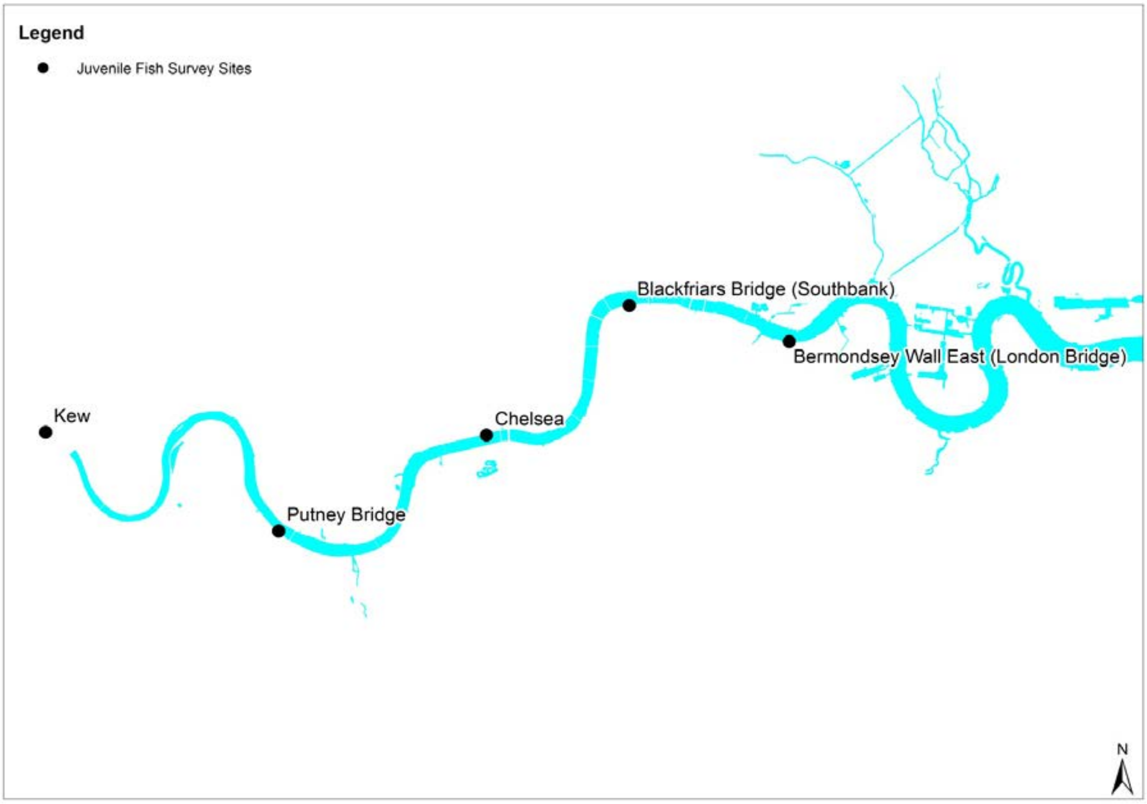
a. Times of first entry of 0-group (first year) individuals into the tidal Thames reaches that would be affected by the ;

b. Fish length distributions at time of first arrival, and changes in length distribution over the rest of the summer/early autumn (indicative of growth and new waves of fish entering the tidal Thames section);

c. Relative abundance (catch-per-unit-effort: CPUE) of fish at each of the survey sites through the summer/early autumn period.

5.4.47 Five sampling stations were used for the 2011 juvenile fish surveys, from Kew upstream to Bermondsey Wall East downstream (Vol 3 Plate 5.4.7). Fish were sampled between May and September with one visit per month, and an additional, second visit within May.

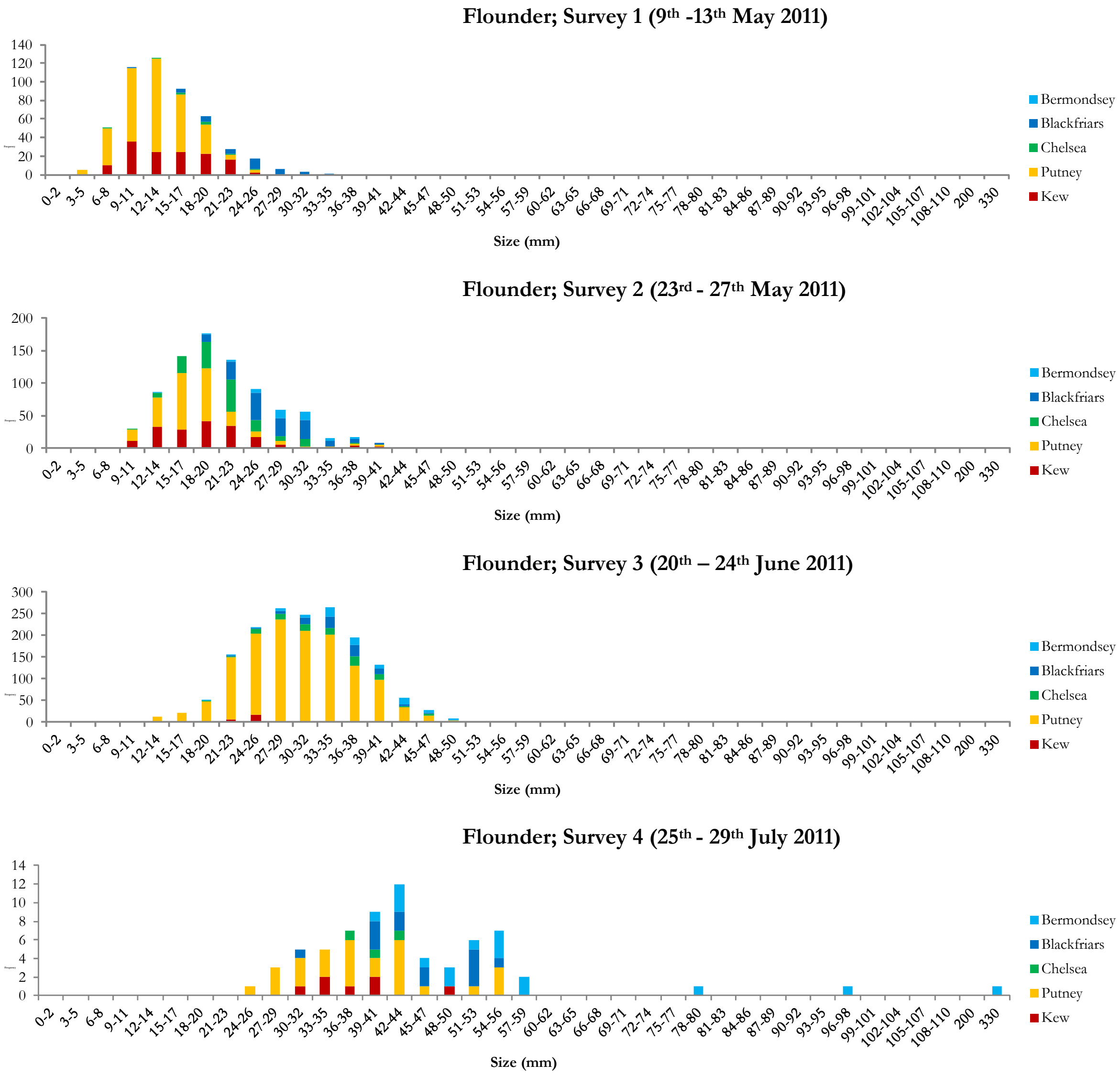
Vol 3 Plate 5.4.7 Aquatic ecology – juvenile fish sampling stations

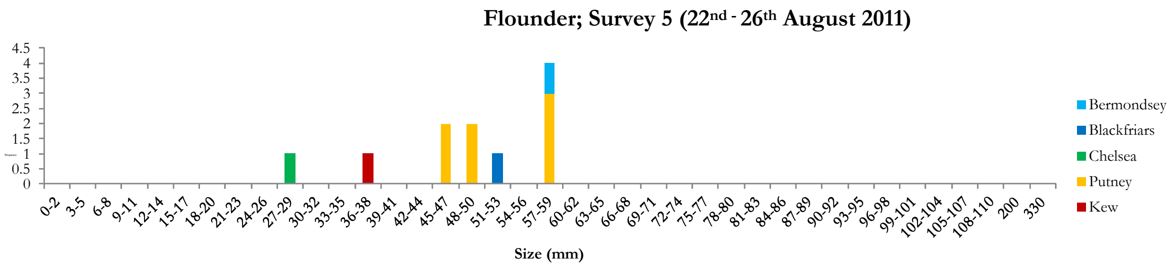


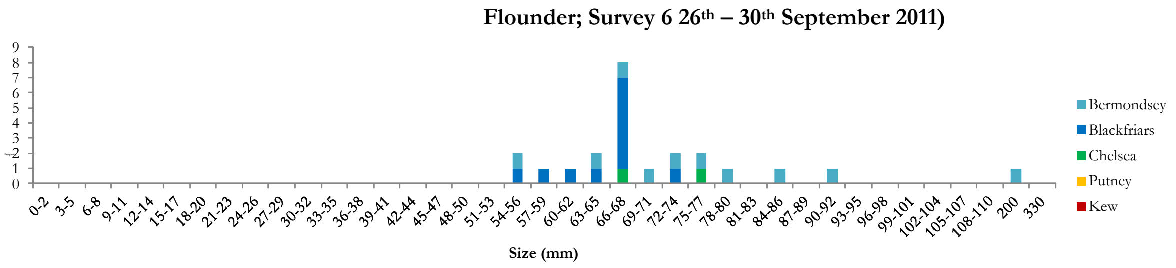
5.4.48 The results of the 2011 juvenile fish survey show that a wide range of species occur consistently in tidal Thames habitats of one metre or less water depth and that many young fish live routinely in water of less than 30cm, ie, the shallow margins.

5.4.49 The distributions of different species within the Thames Upper and Middle reaches shifted during the course of the seasons, indicating the highly mobile nature of these juveniles as they match environmental requirements to the needs of the life stage. The initial incursions of species such as flounder and bass that are spawned in the outer estuary or at sea were rapid and they were found throughout the tidal Thames soon after their first appearance. Vol 3 Plate 5.4.8 shows the pattern of 0-group flounder incursion into the Thames Upper from very small post-larval stages at <10 mm length in May, which then grow over the summer and disperse downstream into the Middle reach by the end of the summer.

Vol 3 Plate 5.4.8 Aquatic ecology - length-frequency distributions of flounder recorded through the series of juvenile surveys

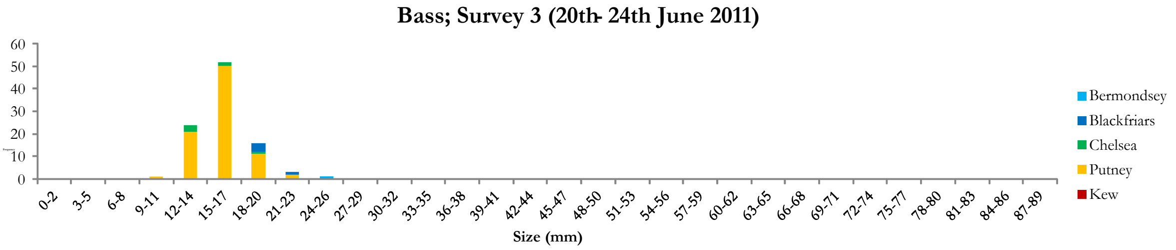


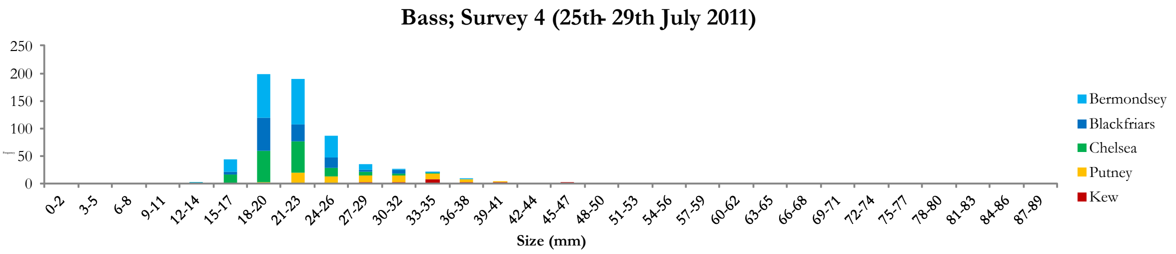


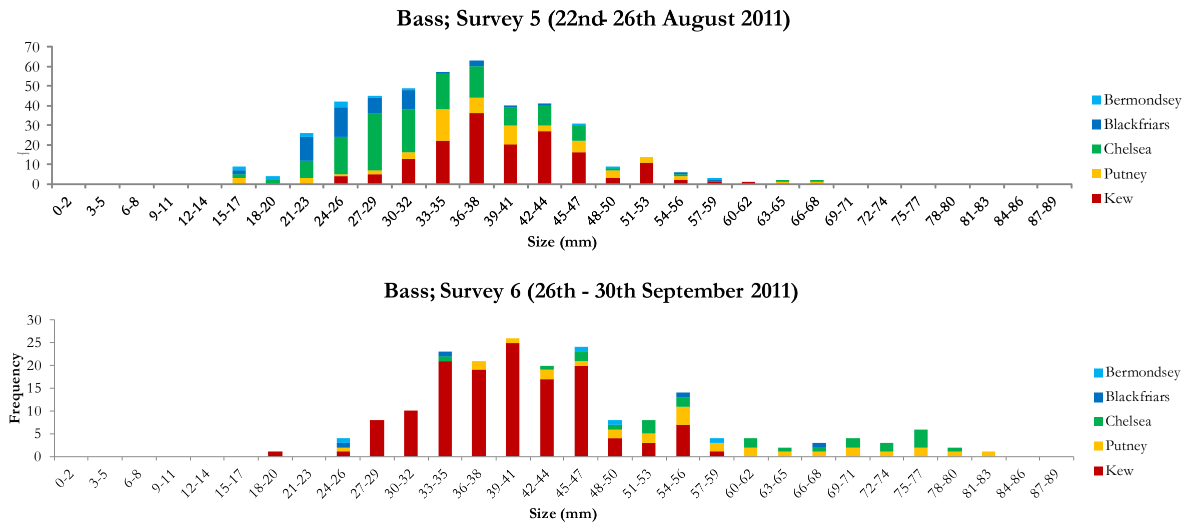


5.4.50 0-group bass (Vol 3 Plate 5.4.9) first appeared in the Thames Upper section in late June (Survey 3) and built up in densities upstream as the season progressed.

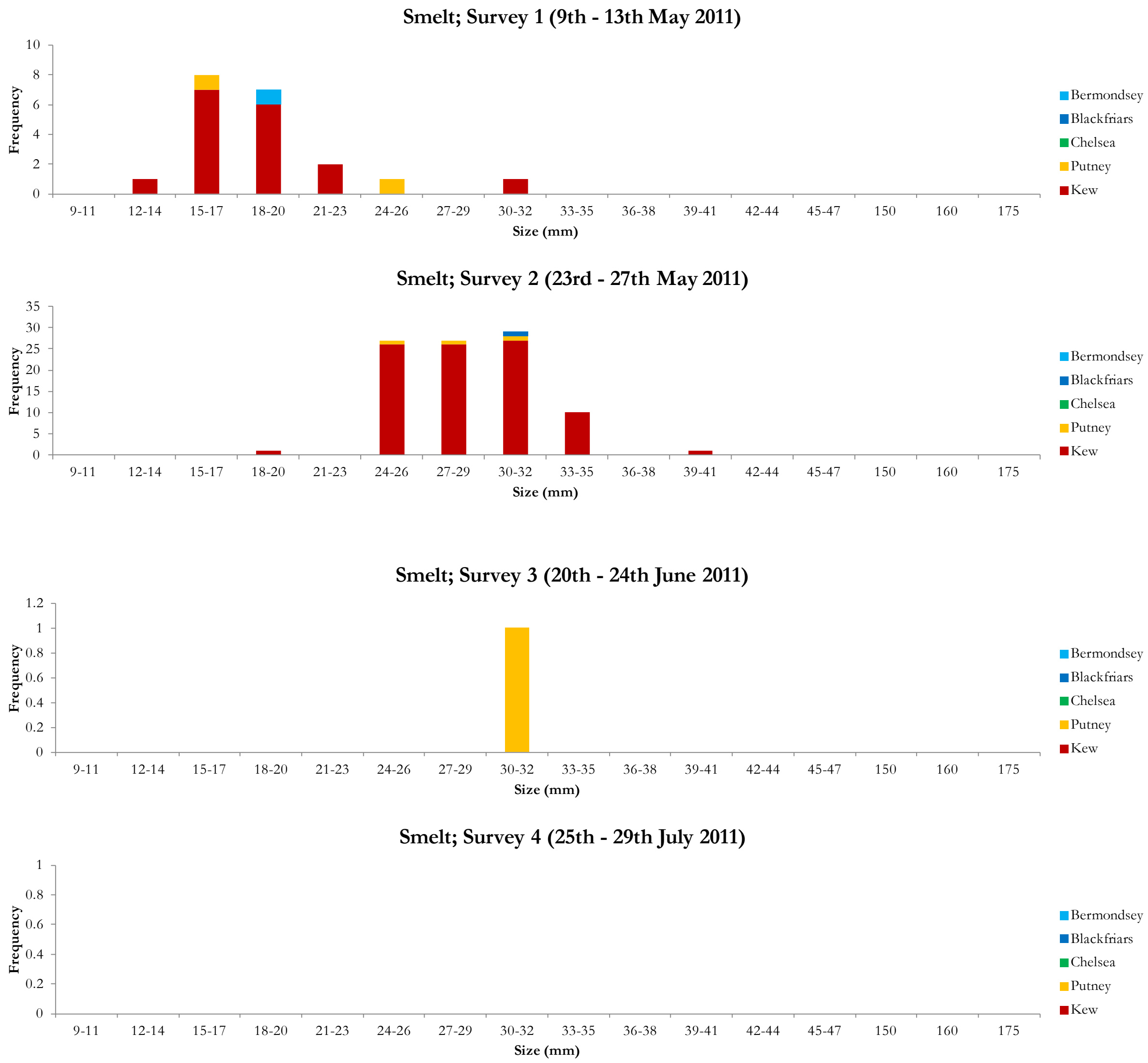
Vol 3 Plate 5.4.9 Aquatic ecology – length-frequency distributions of bass recorded through the series of juvenile surveys

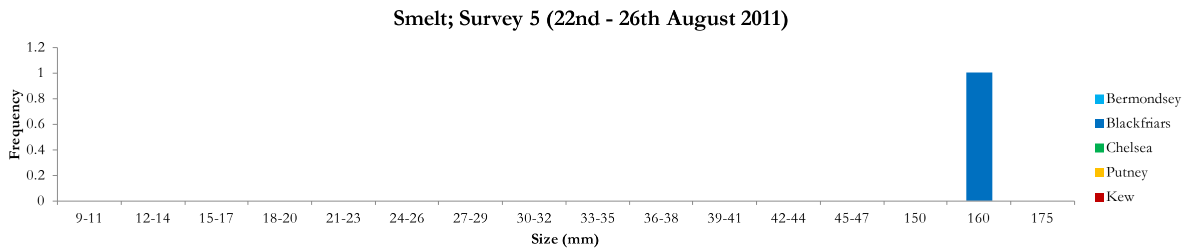


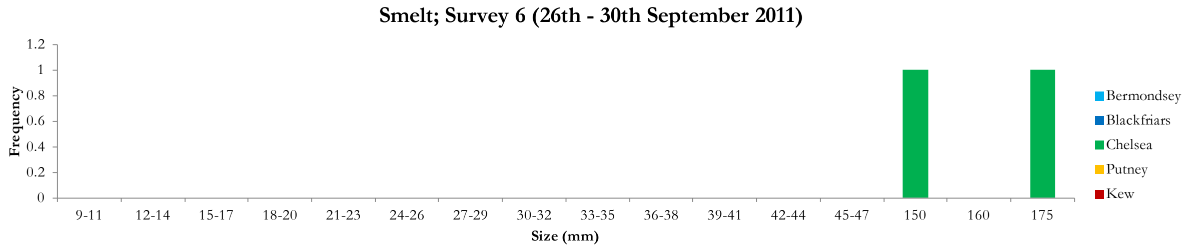




Vol 3 Plate 5.4.10 Aquatic ecology – length-frequency distributions of smelt recorded through the series of juvenile surveys







5.4.51 The case of juvenile smelt is particularly interesting. Juvenile smelt were abundant in the upper reaches around Kew during the May surveys but virtually disappeared following a major CSO spill on 8th June (Vol 3 Plate 5.4.10). Individuals caught in later surveys were older fish, which are more tolerant of hypoxia.

Water quality and current fish baseline

5.4.52 The WFD currently categorises both the Thames Upper and Thames Middle sections of the tidal Thames as being of ‘moderate potential’ in terms of ecological quality. This is predicted to remain the case in 2015, with a target of achieving ‘good potential’ in place for 2027.

5.4.53 Prior to the 1960s, water quality of the tidal Thames was heavily degraded by raw sewage inputs caused by under-capacity of sewage treatment works (STWs) but with the construction of new works, the progressive improvement of fish populations from the 1960s onwards has been recorded (Wheeler, 1979)[25]. The ecology of the tidal Thames has undergone further improvement in recent decades, with some 125 fish species now recorded by the EA. In 2010, the Thames was awarded the International Theiss River Prize in recognition of the progress made and plans in place for improvement, including the Thames Tideway Tunnel project.

5.4.54 However, water quality incidents arising from CSOs still occur frequently on the tidal Thames, some of which do result in fish kills. The most recent of these was in June 2011, about which E A press releases stated:

5.4.55 “The incident ....caused the release of more than 250,000 tonnes of storm sewage into the river from combined sewer overflows and at least 200,000 tonnes of storm sewage from the Mogden Sewage Treatment Works in Isleworth”. A second press release stated. “More than 26,000 fish were killed along a 2 kilometre stretch of the river between Barnes and Chiswick.”

5.4.56 The effects of this incident were picked up in juvenile fish baseline surveys being conducted for the Thames Tideway Tunnel project in 2011, which showed that 0-group smelt were common before the pollution episode but were generally absent throughout the rest of summer; this species is believed to be particularly hypoxia-sensitive (Turnpenny *et al,* 2004)[26] .

5.4.57 The Tideway Fish Risk Model (TFRM) was developed to evaluate proposed DO standards for the tidal Thames (Turnpenny *et al.*, 2004) as part of the *Thames Tideway Strategic Study (TTSS)*. It assimilates data on the seasonal distribution of fish, seasonality and spatial distribution of hypoxic risk and on the lethal sensitivity of different fish species and life stages to hypoxia. Water quality data are input as processed outputs from the WRc Quest model, which, for a given set of DO regulatory standards, can generate the frequency at which a given DO standard is breached over each month of the year and in each tidal Thames AQMS zone. Vol 3 Table 5.4.6 details the current standards, developed under the *TTSS*. Compliance with all four standards, which have different allowable return frequencies, is required. The working principles, methodology and outputs from the TFRM are explained in more detail in Vol 3 Appendix C.3.

Vol 3 Table 5.4.6 Aquatic ecology – TTSS Surface Water Quality Standards for Dissolved Oxygen in the tidal Thames

Standard No.	Dissolved Oxygen (mgL-1)	Return Period (years)	Duration (no. of 6 h tides)
1	4	1	29
2	3	3	3
3	2	5	1
4	1.5	10	1

5.4.58 An explanation of thresholds is provided below:

a. Standard 1 - the DO level in the tidal Thames must not fall below 4mg/l for longer than 29 consecutive tides (approximately equal to one week) on more than one occasion per year.

b. Standard 2 - the DO level in the tidal Thames must not fall below 3mg/l for longer than 3 consecutive tides on more than one occasion every 3 years.

c. Standard 3 - the DO level in the tidal Thames must not fall below 2mg/l for longer than 1 tide on more than one occasion every 5 years.

d. Standard 4 - the DO level in the tidal Thames must not fall below 1.5mg/l for longer than 1 tide on more than one occasion every 10 years.

5.4.59 While complying with the standards should ensure fish sustainability, the TFRM provides a more detailed evaluation for different fish species and life stages. Of the 125 fish species that have been recorded in the tidal Thames , hypoxia tolerances of most are unknown and therefore a subset of seven ‘indicator’ species was selected for the *TTSS* work, for which hypoxia tolerances were measured in the laboratory (Turnpenny *et al.*, 2004)[9] :

a. Brown trout – as a surrogate for Atlantic salmon

b. Smelt

c. Sand smelt

d. Flounder

e. Common goby

f. Dace

g. Bass

5.4.60 These species are among the commonest in EA records and represent a cross-section of fish biology in the tidal Thames. Apart from the salmon and bass, all of these species are known to spawn within the tidal Thames. Bass spawn offshore but are present in large concentrations in the tidal Thames as juveniles (0-group especially) during the summer months. It is important to note that in the development of the DO standards, the fish selected have been adopted not only as surrogates for all fish species in the tidal Thames but for the aquatic ecology as a whole.

5.4.61 TFRM uses the following criteria to assess the effects of hypoxia-related mortality on the sustainability of fish populations in the tidal Thames:

a. Hypoxia events will not affect the sustainability of fish populations if the annual mortality from hypoxia across its whole tidal Thames population is <10%.

b. In the case of some more resilient populations of longer-lived species such as flounder or salmon, up to 30% mortality is sustainable (some exploited commercial fisheries are sustainable at fishing mortality rates in excess of 50%).

c. The TFRM scores the effect of the water quality scenario being examined in terms of the number of unsustainable species/ life stage cases, the ideal being zero.

5.4.62 TFRM baseline results were reported in Turnpenny *et al*. (2004)[27] and Thames Water (2010)[28] and have been updated using the latest available Quests water quality model data and the sustainability criteria explained in para. 5.4.57 to 5.4.58, with further details in Vol 3 Appendix C.3. Under the current baseline (a total of eight species/ life stage cases are expected to exceed the 10% hypoxia-related population level mortality criterion each year. Allowing for mortalities greater than 10% being sustainable in some longer-lived species, five of these eight species/ life stage cases are considered to be unsustainable in the tidal Thames each year. Given that the indicator species act as surrogates for a wider range of ecosystem components, other sensitive taxa are also likely to be unsustainable under this water quality regime.

Tideway fish communities evaluation

5.4.63 Tidal Thames fish communities include a range of species of conservation concern, are highly mobile in nature and include a range of freshwater fish. They form important trophic ecosystem links between benthic invertebrates and, for instance piscivorous birds. The tidal Thames provides a nursery area for primarily marine fish taxa such as gadoids, clupeids, bass, sole and other species. The baseline data as indicated in para. 5.4.56, have indicated that the community value is influenced by water quality and that the sustainability of some populations is threatened by hypoxia. Given this, and the wide range of ecological and socio-economic values, the overall tidal Thames fish community is given a high (regional) value.

Invertebrates

5.4.64 This section presents a summary of the baseline information relating to invertebrates within the study area. The available baseline data consists of long-term EA sampling from a range of tidal Thames sites; and data collected specifically for the Thames Tideway Tunnel project during October 2010 at sites which have been selected as potential foreshore construction sites.

5.4.65 Further surveys were undertaken in May 2011. The 2011 surveys included a suite of samples in the vicinity of the largest CSOs (i.e. those with a combined spill volume of greater than 1 million m^3 per year) in order to try and determine the effects of the discharge on benthic invertebrates. The sites were Cremorne Wharf Depot/Lots Road Pumping Station, Deptford Storm Relief and Abbey Mills. Samples were taken in the immediate vicinity (within 50m) of the discharge, and a further suite of control samples were taken beyond 200m from the discharge. Any differences in the invertebrate communities between these samples would provide an indication of the improvements which may be expected to occur in the vicinity of CSO discharges following interception by the main tunnel.

5.4.66 The purpose of this section is to highlight the patterns of distribution of the invertebrate community and the function of the tidal Thames as a habitat resource in order to inform the project-wide assessment. Raw data from both survey and background sources are presented in the following paras, and a more detailed analysis is provided in the baseline report provided in Vol 3 Appendix C.1.

5.4.67 Specifically, the following section focuses on the following main areas:

a. A summary of the findings of the October 2010 and May 2011 surveys of Thames Tideway Tunnel project sites.

b. An overview of invertebrate community composition and its change with distance through the tidal Thames.

c. An analysis of the factors determining invertebrate distribution, particularly the influence of DO concentrations.

d. The presence of rare and notable species.

e. The nature and range of notable habitats for invertebrates through the tidal Thames.

5.4.68 In both the October 2010 and May 2011 surveys, invertebrate diversity was generally low. The least diverse sites included King Edwards Memorial Park, and King Stairs Gardens. Sampling was carried out at

King Stairs Gardens in October 2010 since at that time a foreshore site was proposed here. The site was subsequently replaced by Chambers Wharf. Data for the site has been used in the analysis as it provides additional information about the invertebrate communities which occur in this reach of the river. The approach to the invertebrate sampling programme and a complete list of sites is provided in Vol 2 Section 5.

5.4.69 At some of the more downstream sites (notably Deptford Church Street and Blackfriars Bridge Foreshore) there tended to be greater differences in diversity between subtidal and intertidal samples, with intertidal samples being characterised by lower diversity.

5.4.70 The most diverse sites tended to be further upstream (in both intertidal and subtidal samples), notably at Hammersmith Pumping Station, Barn Elms, and Putney Embankment Foreshore.

5.4.71 *Potamopyrgus antipodarum* and *Radix balthica* (snails) are commonly occurring species that are distributed throughout the tidal Thames. They are present in high abundances in the subtidal zone at a number of sites. These snails are generally considered to be tolerant to organic pollution and are only likely to be impacted by very high levels of biochemical oxygen demand (BOD). However, they are less mobile than other invertebrates and take more time to colonise habitats after they have been disturbed. Although their distribution is likely to be highly influenced by habitat (eg, areas of deposition, slow flowing areas), sites with very low abundanc or absence may indicate intermittent/recent levels of very high pollution. Conversely very high abundance may be indicative of enriched water.

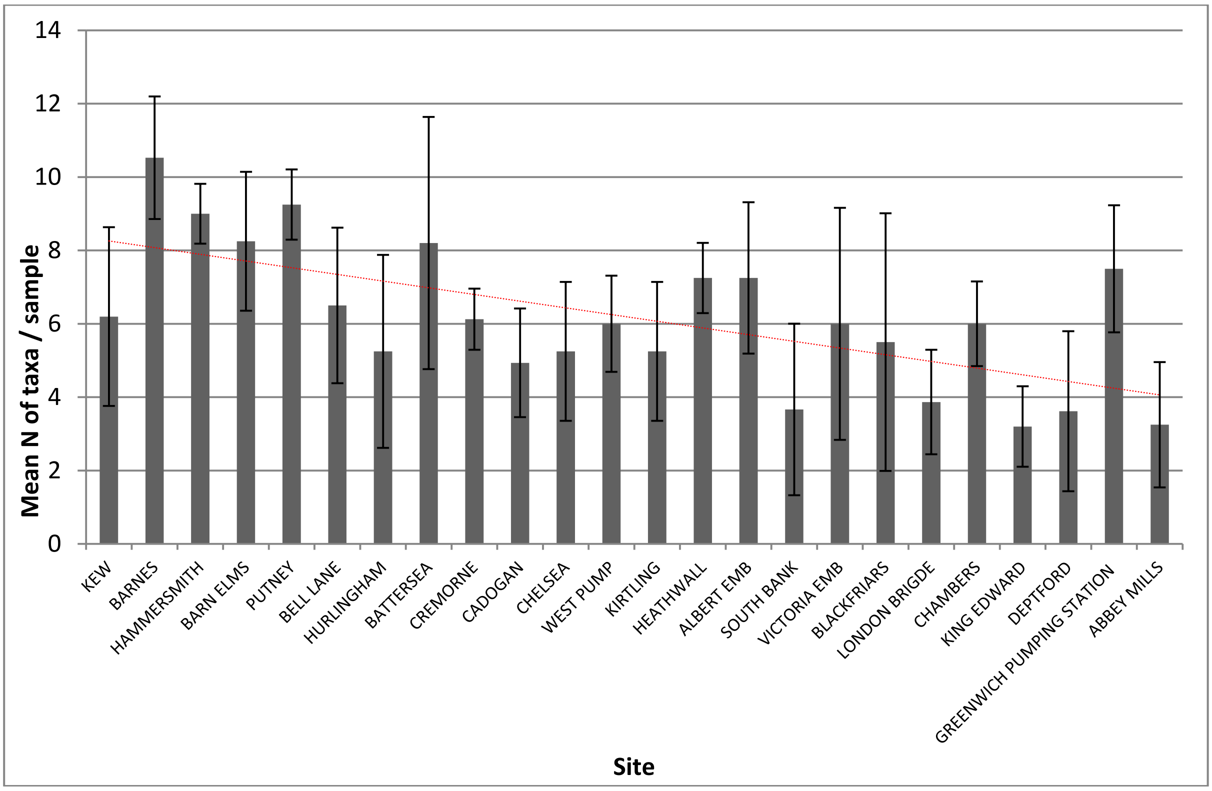
5.4.72 Oligochaeta (segmented worms) are generally associated with organically enriched water. During May 2011, they were present in high numbers at sites that appear to have less suitable physical conditions (e.g. coarse substrate, low width of intertidal zone) and/or within close proximity of the large CSOs (para. 5.4.65). However, they were generally absent in such high numbers at other sites that otherwise appeared to be of low habitat suitability and/or within close proximity of CSOs (such as King Edward Memorial Park). Oligochaetes can sometimes be absent from enriched sites when the source of organic pollution is intermittent (such as CSOs if they discharge less regularly). This is because a constant source of organic input is required for tolerant groups to develop.

5.4.73 The following section presents a summary of the baseline data collected during surveys during October 2010 and May 2011; and EA background data for a number of sites in the tidal Thames collected between 1989 and 2011.

5.4.74 The average number of taxa recorded per sample using kick and airlift sampling methods at 18 sites between Kew and Deptford Church Street is presented in Vol 3 Plate 5.4.11. The graph illustrates that there is an overall decrease in the number of taxa per sample from upstream to downstream, with a peak of 12 species at Barnes to a minimum of one at South Bank Centre. This is correlated with increasing salinity, which is to be expected since only a relatively small number of invertebrate taxa are able to tolerate the fluctuations in salinity which occur within the brackish zone.

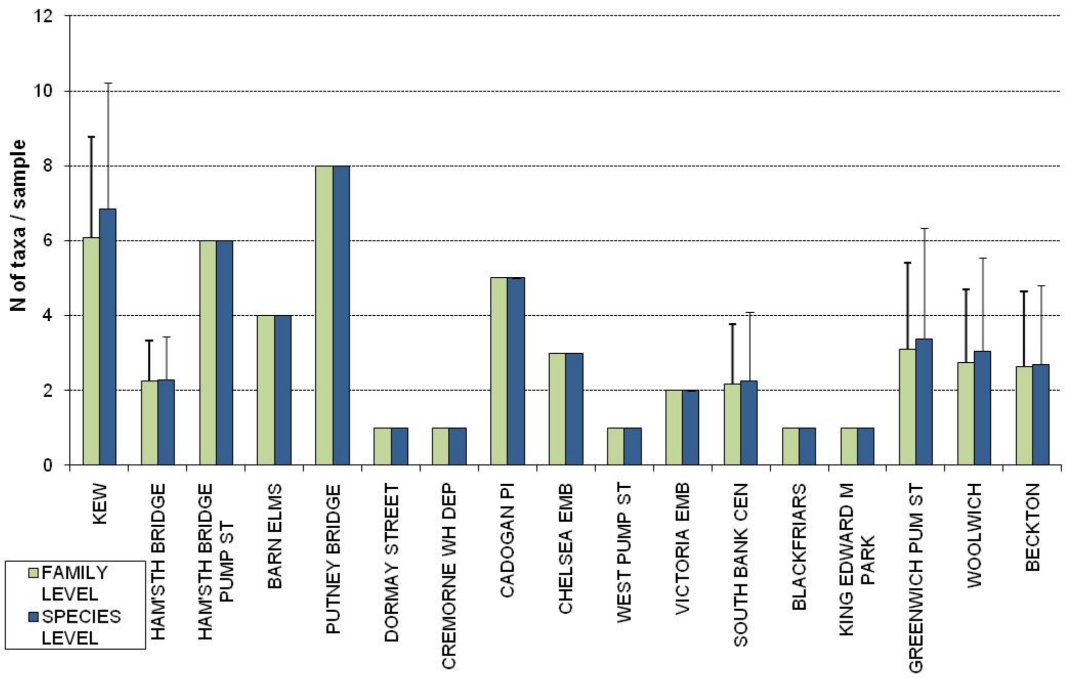
5.4.75 However, the transition is not without interruption, and there are exceptions to the trend. These are likely to represent localised differences at the sampling sites - for example in distribution of habitat and substrate at sampling stations, local sources of pollution and sampling variation.

Vol 3 Plate 5.4.11 Aquatic ecology - mean number of invertebrate taxa recorded in the tidal Thames from 1989 to present



5.4.76 The mean number of taxa recorded per sample using core, grab and quadrat sampling methods at 16 sites between Kew and Beckton is shown in Vol 3 Plate 5.4.12 below. These results show the highest diversity at three of the five most upstream sites surveyed, though differences in numbers of taxa are generally small.

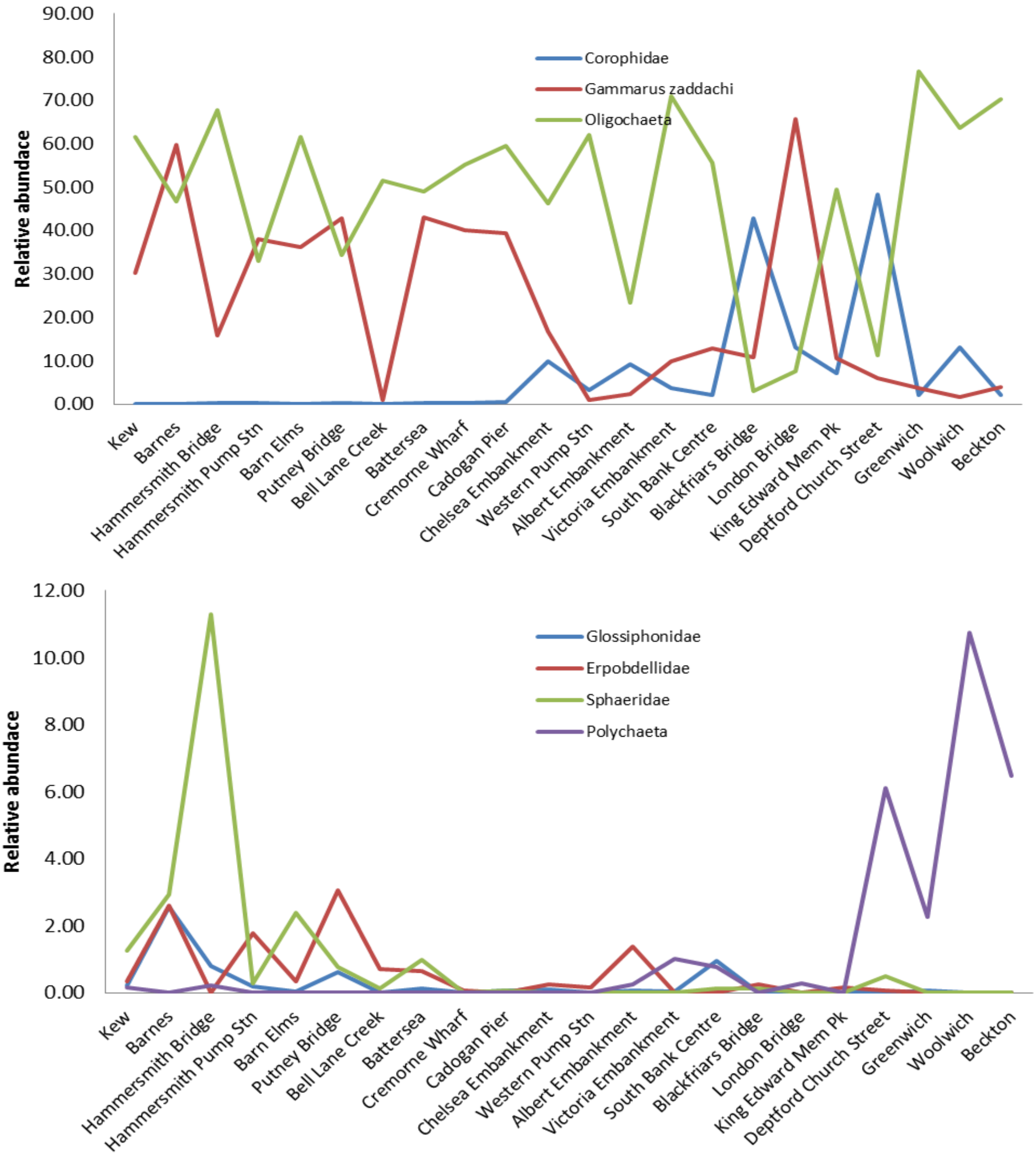
Vol 3 Plate 5.4.12 Aquatic ecology – mean number of invertebrate taxa recorded in the tidal Thames from 1989 to present



5.4.77 In addition to the trends in the number of taxa, the invertebrate communities are characterised by different taxa in samples moving downstream through the tidal Thames.

5.4.78 Vol 3 Plate 5.4.13 shows a 'snapshot' of how certain key taxa change with distance downstream. The data set illustrated combines all data from each year using all of the different methods, including those collected during field surveys undertaken in 2010 and 2011. Relative abundance has been used to avoid bias brought about by the different sampling methods used. The figure demonstrates how mostly freshwater groups such as leeches (Erpobdellidae, Glossiphoniidae), insects and pea mussels (Sphaeridae) are replaced further downstream by groups such as worms (Polychaeta) and mudshrimp (Corophiidae). Estuarine species such as the freshwater amphipod *Gammarus zaddachi* are fairly ubiquitous due to their tolerance of saline fluctuations although they eventually decrease at sites downstream of King Edward Memorial Park Foreshore. Oligochaeta appear to mostly ubiquitous throughout the length of the tidal Thames considered, although there are three downstream survey locations (Deptford Church Street, Blackfriars Bridge Foreshore and London Bridge) where they are significantly less abundant.

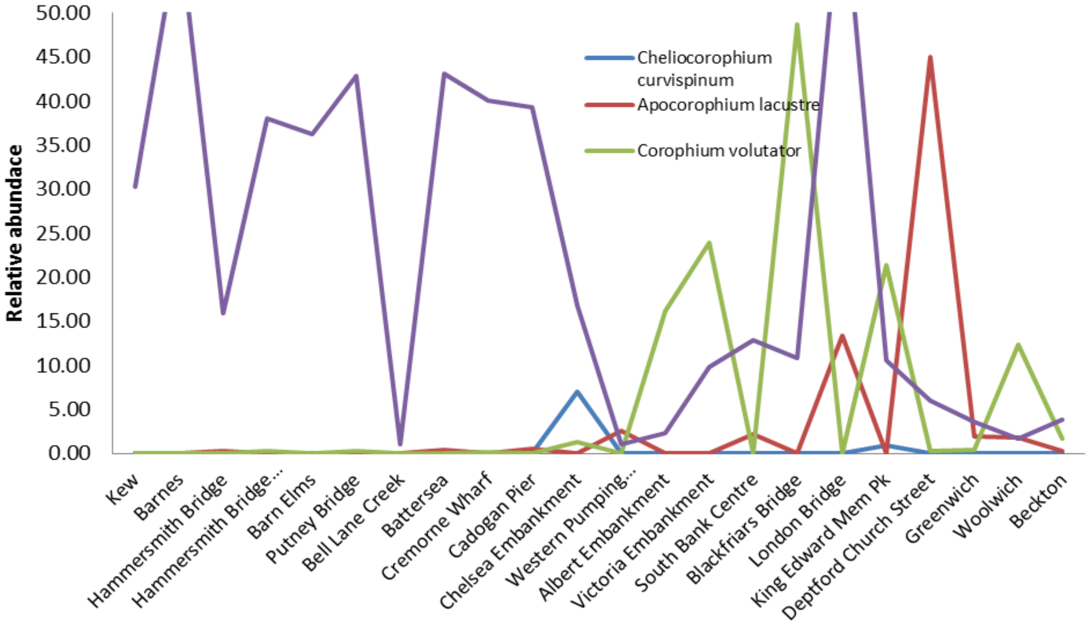
Vol 3 Plate 5.4.13 Aquatic ecology – distribution of invertebrate taxa through the tidal Thames



5.4.79 The importance of distance downstream and resulting differences in saline influence and habitat is further demonstrated in Vol 3 Plate 5.4.14, which show the distribution of different species Amphipoda (crustaceans: shrimps and mudshrimps). This illustrates the succession of species with distance down the estuary

5.4.80 One such crustacean species, the freshwater amphipod *Gammarus pulex* is limited to the most freshwater extreme of the tidal Thames, and is most abundant at Barnes and Kew. It is intolerant of even infrequent saline intrusion, and is not present further downstream as the water becomes more brackish. *G. zaddachi* on the other hand is fairly ubiquitous and is abundant at most sites between Kew and London Bridge, but decreases at sites downstream of King Edward Memorial Park Foreshore. The three species of Corophiidae (*Cheliocorophium curvispinum*, *Apocorophium* *lacustre*, *Corophium volutator*) on the other hand are mostly abundant in the lower reaches of the tidal Thames, with *A. lacustre* and *C. volutator* appearing to have a distribution closer to the estuary compared with *C. curvispinum*.

Vol 3 Plate 5.4.14 Aquatic ecology – distribution of species of Amphipoda through the tidal Thames



5.4.81 The varying level of salinity and saline fluctuations appear to correlate with the diversity and structure of benthic invertebrate assemblages. Generally, invertebrate communities were dominated by species tolerant of fluctuations in salinity. The community is characterised by a larger proportion of worm taxa (Oligochaeta and Polychaeta), Crustacea and snails, compared with the freshwater environment where insect taxa tend to dominate in terms of species diversity and abundance. Even at the most upstream site Kew, few obligate freshwater species or taxa were recorded.

5.4.82 The majority of species present are considered to be relatively tolerant of organically polluted conditions, with few 'clean' water indicators present. The species generally considered to be most sensitive to organic pollution is the river neritid snail, *Theodoxus fluviatilis* (Neritidae) (as shown in various studies, for example (Walley and Hawkes, 1996)[29] (Walley and Hawkes, 1997) [30], which is a species found in freshwater and brackish waters.

5.4.83 It was most abundant in upstream sites and, based on EA records, appears to have colonised many of the sites relatively recently. The relatively low abundance of *Theodoxus* in many of the downstream sites correlates with increased salinity lower down in the tidal Thames. However, the presence of this invertebrate species at Deptford Church Street suggests that factors other than salinity (for example, localised habitat availability or water quality) may be a limiting factor in some sites further upstream.

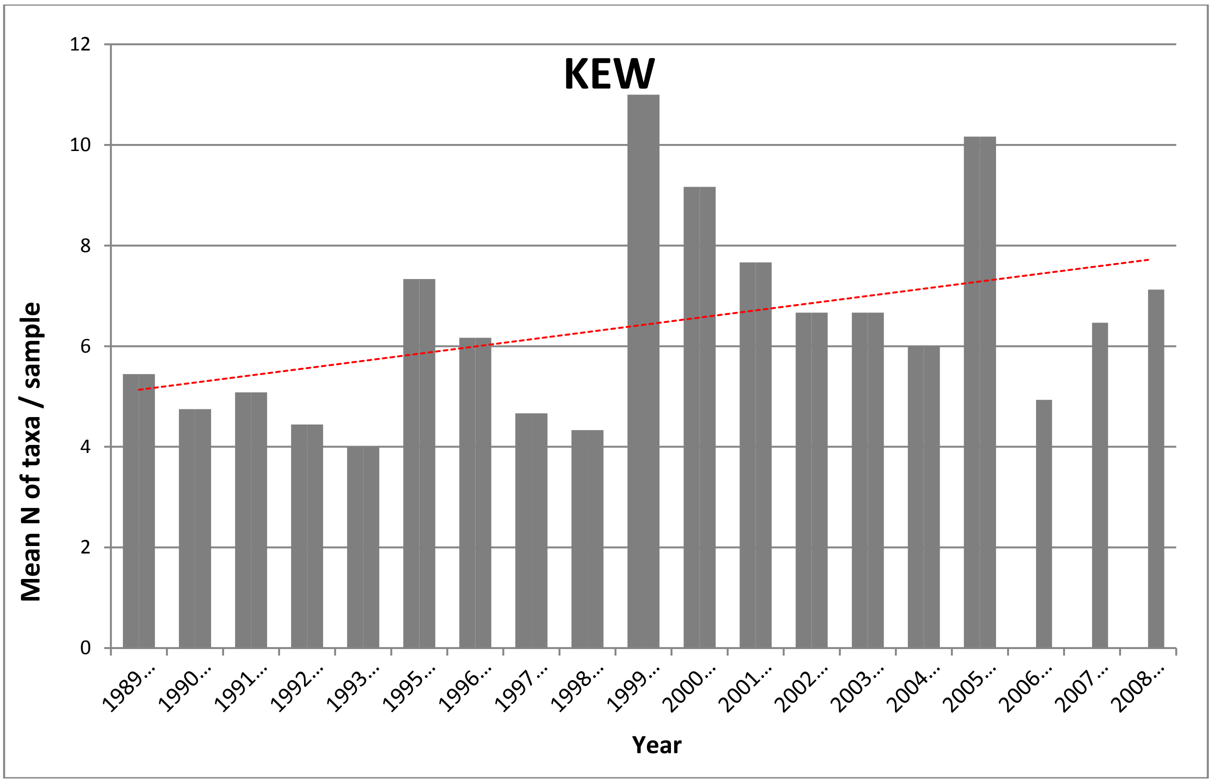
Changes in invertebrate community composition between 1989 to 2010

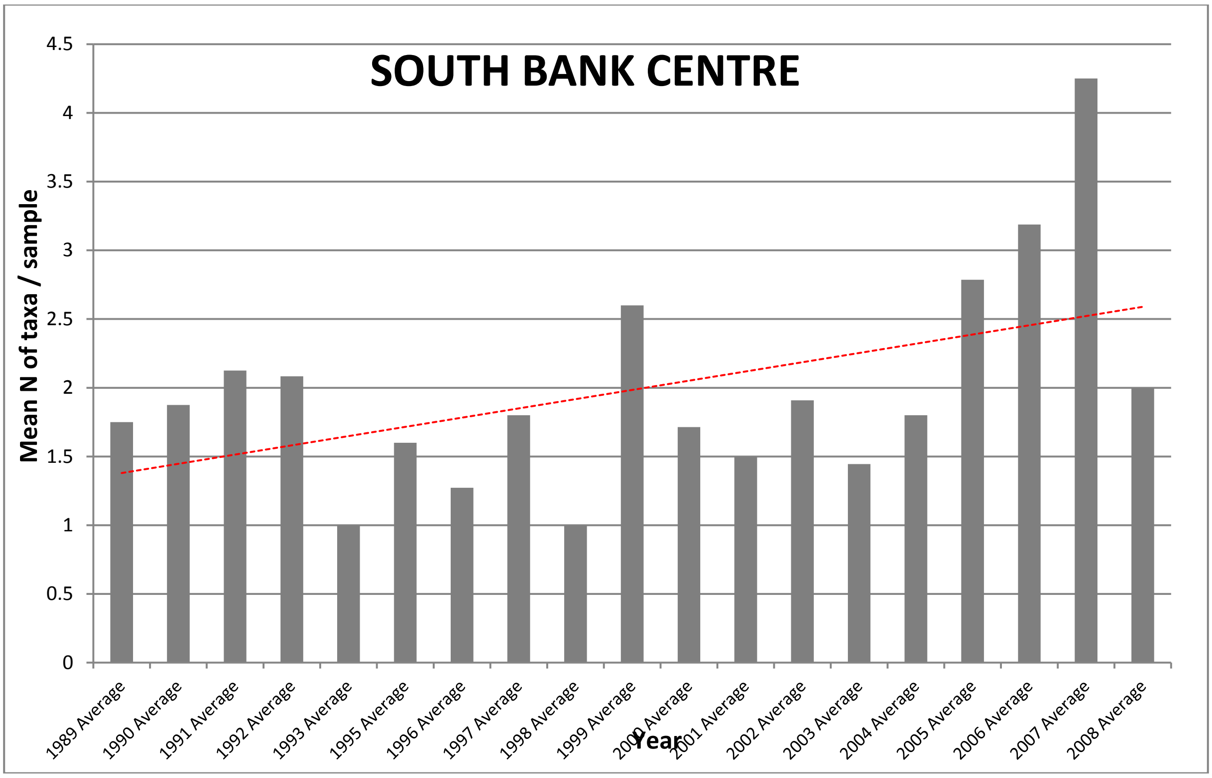
5.4.84 Using the EA data, it has been possible to evaluate some of the key changes in the invertebrate assemblages sampled since 1989. However, data are not available for every site each year and sampling for a number of sites ceased during this time period, while for other sites, sampling only commenced relatively recently.

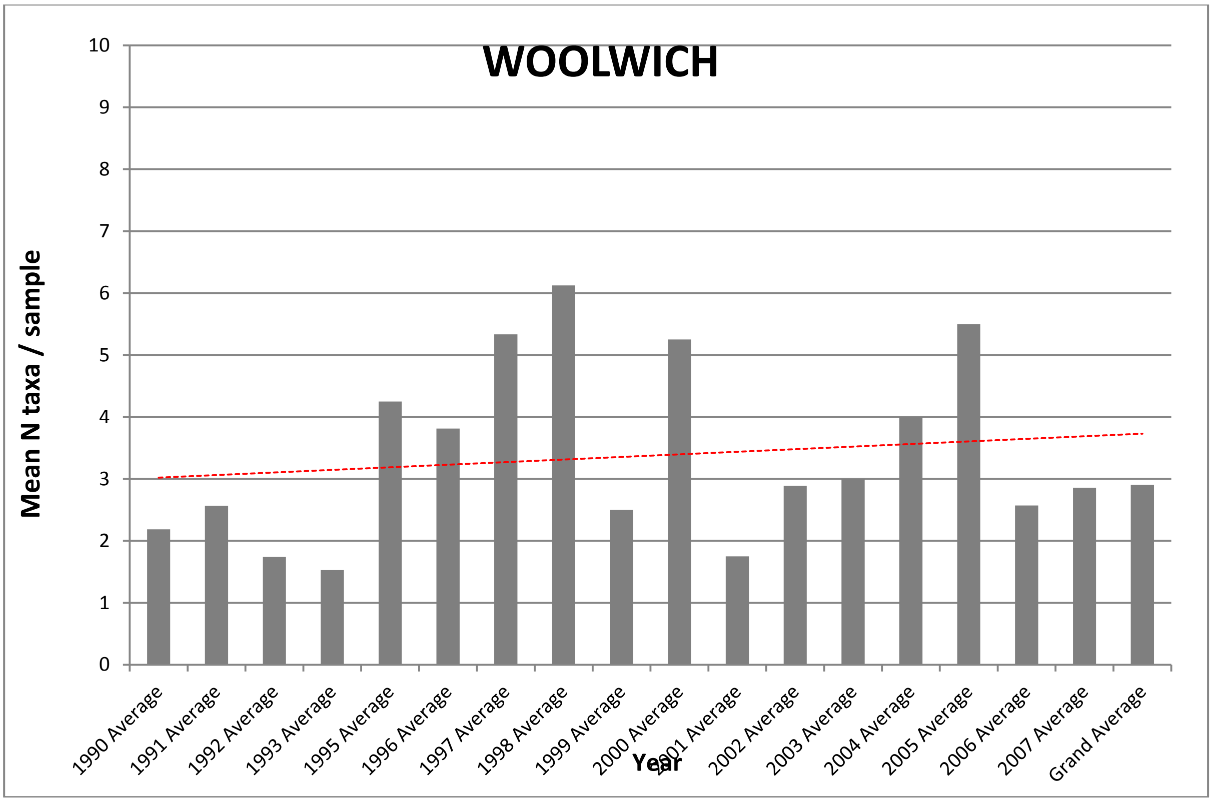
5.4.85 Therefore, only four sites for which there is a complete or near complete data set are illustrated in this section. These sites are Kew, South Bank Centre, Woolwich and Beckton.

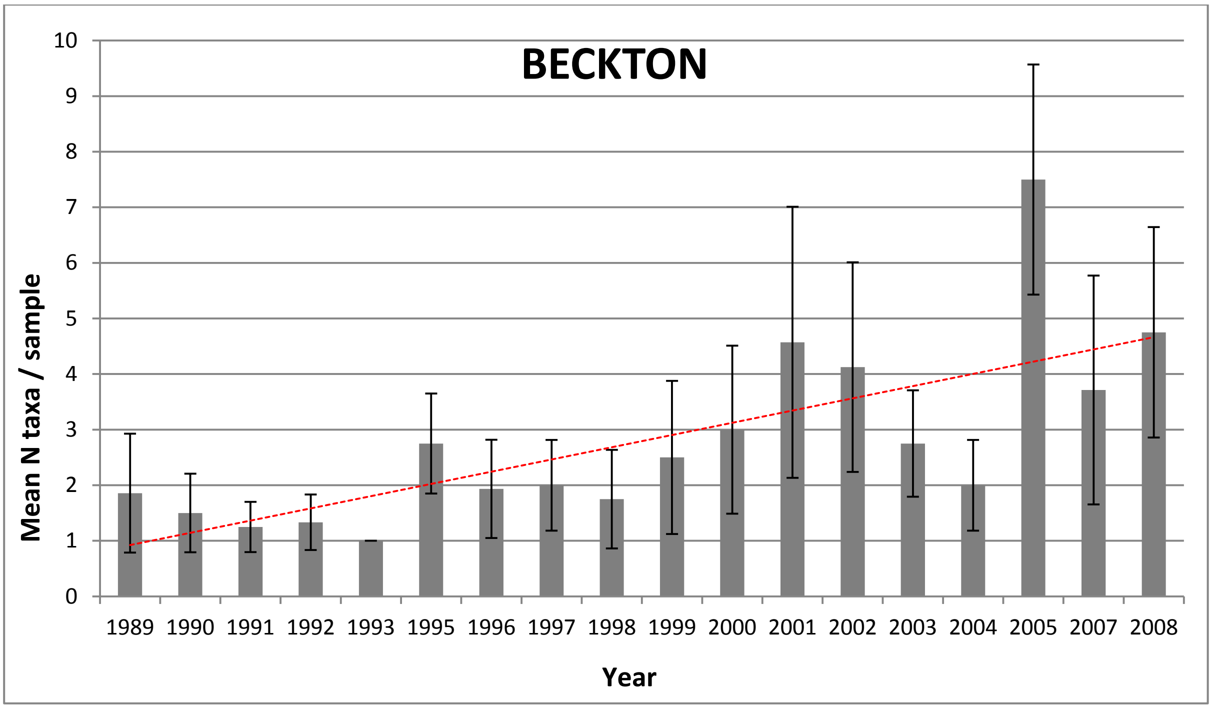
5.4.86 Vol 3 Plate 5.4.15 shows how species diversity has varied since sampling commenced at these four sites in the tidal Thames. The data has been adjusted so that inconsistencies in identification levels, nomenclature and sample methods are removed.

Vol 3 Plate 5.4.15 Aquatic ecology – invertebrate species at four sample sites




SOUTH BANK CENTRE
Mean N of taxa / sample
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
1989 Average
1990 Average
1991 Average
1992 Average
1993 Average
1995 Average
1996 Average
1997 Average
1998 Average
1999 Average
2000 Average
2001 Average
2002 Average
2003 Average
2004 Average
2005 Average
2006 Average
2007 Average
2008 Average
Year


WOOLWICH
Mean N taxa / sample
0
1
2
3
4
5
6
7
8
9
10
1990 Average
1991 Average
1992 Average
1993 Average
1995 Average
1996 Average
1997 Average
1998 Average
1999 Average
2000 Average
2001 Average
2002 Average
2003 Average
2004 Average
2005 Average
2006 Average
2007 Average
Grand Average
Year



Note: (adjusted to common taxa level)

5.4.87 Vol 3 Plate 5.4.15 illustrates a high level of year-on- year variability at each of the sites. This is most clearly manifested from samples taken at Woolwich where a consistently low number of taxa per sample were recorded for the first seven years (1989 to 1996) followed by a sudden increase in 1997, a decline and further peak in 2005.

5.4.88 What is also notable from sample data from Kew, South Banks Centre and Beckton is that, although there is no clearly defined trend (smooth increase or decrease) in invertebrate species diversity, the majority of poorer years in terms of species number occurred earlier in the data set (before 1997), while most of the higher taxa richness was recorded more recently.

5.4.89 Further analysis of the data has been undertaken to assess to what extent annual variations in invertebrate communities is due to water quality issues or other factors, based on water quality data and predictions.

5.4.90 A series of statistical techniques were used to identify trends and associations in the dataset. They were:

5.4.91 Cluster analysis (the process of assigning objects (samples in this case) into groups, such that the objects in that group are more similar to each other than to those in other groups. It was used to analyse the invertebrate data and determine whether they form definite clusters of species).

5.4.92 Principal Components Analysis (PCA) was applied to understand the structure and relationship between objects (samples and sites) and variables (invertebrate taxa or environmental variables).

5.4.93 Redundancy Analysis (RDA) was applied to understand the influence of chemical variables on the composition/abundances of the invertebrate assemblages.

Cluster analysis

5.4.94 Cluster analysis reveals a number of patterns within the tidal Thames data set. Most importantly, that the data varied significantly depending on (a) different measures of abundance or presence/absence data; and (b) the sampling method used. Core, grab, gulley dredge and quadrat samples tended to cluster together, as did three-minute kick and airlift samples. Separating samples into two groups based on sampling methods was necessary as the difference between different sampling methods otherwise obscured clusters that could be attributed to other factors.

5.4.95 The cluster analysis showed that, in general, samples in the brackish zone were less diverse compared with samples taken in the freshwater zone of the tidal Thames. This concurs with previous research into the invertebrate community of the tidal Thames and other estuaries, which show diversity decreasing downstream as the saline influence increases. This is generally attributed to the fact that relatively few invertebrates are adapted to significant fluctuations in salinity. Other factors such as poor water quality and lack of habitat diversity, particularly in central London, are also likely to contribute to a smaller extent and on a more localised scale.

5.4.96 The relative abundances of two taxa, Oligochaeta and Gammaridae determined where in the cluster the samples were organised, showing that the relative abundance of these two taxa is responsible for the main differences between clusters. This was independent of the sampling site position in the tidal Thames and it can therefore be concluded that the invertebrate assemblages were influenced by factors other than salinity, though it must be borne in mind that within these taxa there exist species with a range of saline tolerances.

5.4.97 Gammaridae are known to prefer complex, well aerated habitats in contrast to Oligochaeta, which are typical of simpler, silty, less well aerated habitats.

Principal Components Analysis (PCA)

5.4.98 The PCA shows that, throughout the length of the tidal Thames, the invertebrate community is dominated by a small number of taxa. The tide moves water up and downstream for several kilometres twice daily, carrying with it a saline ‘wedge’, and associated differences in temperature, silt, organic matter, and other materials. The distance this saline ‘wedge’ travels up and downstream is variable (depending on freshwater flow, tide etc) meaning that the at any given site there is considerable variability in minimum/maximum salinity between seasons and years; thus in terms of its saline profile, no given site or area of the tidal Thames has a ‘set’ profile and its fauna is likely to reflect the variability.

5.4.99 During hot summers and low flows, tidal movements also move oxygen sags and associated issues of poor water quality. Thus a large contrast in water quality and invertebrate fauna should not be expected between sites upstream and downstream of significant discharges, such as CSOs or STW.

5.4.100 Within the upper estuary (including sites from London Bridge to Kew), the most dominant taxa were Oligochaeta and Gammaridae, whose abundances tended to be negatively correlated with one another throughout the river. This is in agreement with the results of the cluster analysis. Hydrobiidae (mud snails) also contributed significantly to the variation observed, although the analyses showed that this taxon was not correlated with either Oligochaeta or Gammaridae. The abundance of these groups does not appear to be associated with any specific sites along the tidal Thames, and in this context it should be noted that these taxa contain a range of saline tolerance between species. Freshwater taxa were also present, including leeches and river neritid snails (which characterised the Barnes sample site) and Sphaeridae (pea snails - most dominant at the Kew sample site).

5.4.101 Within the brackish zone (downstream of London Bridge to Beckton), taxa such as the Polychaete family Spionidae and mudshrimp Corophiidae significantly contributed to the invertebrate community structure, although taxa such as Oligochaeta, Gammaridae and Hydrobiidae also appeared to be significant. Spionidae are a family of Polychaete worms found in brackish, rather than freshwaters. Their abundance, which was highest at downstream sites (notably Woolwich), is indicative of the saline influence on the invertebrate community.

Redundancy Analysis (RDA)

5.4.102 The RDA, combining the chemical and invertebrate data, demonstrates the importance of environmental variables in determining the invertebrate communities in the tidal Thames. It appears that dominance of either Gammaridae (sensitive to hypoxia) or Oligochaeta (more tolerant to hypoxia) is influenced by the DO concentrations and DO sags in the tidal Thames, although other factors such as habitat are also highly important. Other invertebrate taxa also appeared to be affected by poor water quality (low DO) and/or saline intrusion, notably the insect group (mayflies), while other groups (essentially Polychaete and Oligochaete worms) were shown to be tolerant of these conditions. Given the contribution of CSO discharges to these DO sags, these findings can be considered as significant in terms of understanding how storm water discharges affect the tidal Thames.

5.4.103 For several analyses, certain taxa (notably Gammaridae) were shown to be positively correlated with high ammonia concentrations. This is likely to be due to the fact that, at many sites, ammonia is negatively correlated with high DO, rather than reflecting any direct positive influence of ammonia on any invertebrates. Ammonia levels were generally low (at concentrations that wouldn’t affect invertebrates).

5.4.104 The variations in the structure of invertebrate communities and the determining environmental factors briefly described above are considered at a site specific level in the following sections. Sites within the freshwater zone (Kew and Cadogan Pier) first, followed by those in the brackish zone (Greenwich and Beckton).

Upper Tideway

5.4.105 In the upper freshwater zone (Kew and Cadogan Pier sample sites), the most significant variations were the abundances of Gammaridae and Oligochaeta. Whether Oligochaeta or Gammaridae is dominant is largely due to the types of habitat sampled; Oligochaeta are found more frequently in poorly oxygenated silt while Gammaridae are found more frequently in shingle dominated sediments. Both types of habitat are likely to be present in different areas of the Kew sample site.

5.4.106 However, the PCA analysis of Kew and Cadogan Pier demonstrated that there are also seasonal patterns, with Oligochaeta more frequently dominant compared with Gammaridae in summer and autumn samples. The seasonal variation between these two groups has previously been described in studies of the Thames invertebrate communities from the early 1990s (Attrill, 1998)[31], which suggests *G. zaddachi* (the dominant species of Gammaridae in the tidal Thames between Kew and Gravesend) is effectively a 'winter' species. No explanation of these trends was provided in this previous study. However, as discussed in paras. 5.4.102 to 5.4.104, the RDA analyses of environmental and biological variations at Kew and Cadogan Pier seem to provide some correlations, which may help to explain this and other temporal variations in the upper tidal Thames.

5.4.107 The environmental data appear to explain, at least in part, the variations in biological assemblages sampled on the tidal Thames at Kew and demonstrate how the invertebrate fauna at Kew is affected by DO concentrations and DO sags. The apparent correlations between mean DO concentrations and the frequency/duration of low DO events and the abundance of Oligochaeta and Gammaridae are also notable. The negative correlation between low DO events and reduced Gammaridae is consistent with observations of Gammaridae coming to the surface (for oxygen) during periods of hypoxia[32]. However, it is likely that other factors (notably local variations in habitat) also play a significant role.

5.4.108 For some observations, it is difficult to determine which environmental parameters are influencing the invertebrate communities the greatest and it is likely that there are cumulative effects. As demonstrated by the RDA and PCA, low DO concentrations tend to occur at the same time as low summer flows and thus tend to be associated with a slight increase in salinity at Kew. Many freshwater invertebrates, notably insects, are intolerant to even the smallest increase in salinity, even when it occurs for a very short duration, and it is therefore difficult to discriminate between variations associated with water quality and those associated with salinity.

5.4.109 Therefore, for many of the invertebrates that appeared to be adversely affected by low DO concentrations at Kew (notably mayflies (Caenidae, Ephemerillidae), flatworms (Planariidae), snails, (Neritidae, Physidae), freshwater mussels (Dreissenidae), leeches (Glossiphoniidae, Erpobdellidae), caddis flies (Leptoceridae), true flies (Psychodidae), midges (Chironomidae) no clear distinction between the effects of increased salinity and low DO could be demonstrated by the RDA, as they generally occurred during the same six month periods (warm, dry summers).

5.4.110 However, there are a number of DO sensitive, brackish water taxa which help to separate the effects of these two environmental variables. The species of the amphipod Gammaridae present in samples from Kew was almost exclusively *G. zaddachi*, a brackish species present as far down in the tidal Thames as Gravesend (Attrill, 1998)[33]. The drop in abundance of this species correlated with high flows and DO concentrations/events observed is more likely to be due to changes in DO than any change in salinity.

5.4.111 The abundance of the mayfly species (*Caenis luctuosa)*, a euryhaline (tolerant to varying saline levels) species Perran *et al*, 1999)[34] is correlated with better water quality (high DO concentration) years. Likewise, some other groups that appear to be impacted by low DO during warm summers are similarly tolerant of the highest saline concentrations recorded at Kew, including *Dreissena polymorpha* (the only species of Dreissenidae), and many species of Physidae (Costil *et al*, 2001[35]; Drieir and Tranquili, 1981[36]).

5.4.112 Similar patterns were observed in Cadogan Pier samples. For example, the apparent correlations between mean DO concentrations and the frequency/duration of low DO events and the abundance of Oligochaeta and Gammaridae are also notable. However, the group of invertebrates that are negatively correlated with low DO (and/or salinity) is much smaller, and comprise mainly Gammaridae, Chironomidae and Lymnaiedae (snails). The reasons for this are not clear. However, it is likely that the following factors are determinant: (a) downstream position of the sample site, subject to greater variations in salinity and therefore lower invertebrate diversity; (b) the reduced period in which samples taken (three years, compared with sixteen years at Kew); (c) the distance from upstream sources of migration; and (d) possible poorer habitat.

5.4.113 Another significant difference compared with Kew is that Erpobdellidae appear to be associated with poor water quality. However, only a very limited number of Erpobdellidae were recorded at Cadogan Pier (*Erpobdella testacea*), while at Kew several species were recorded in high abundances (including *Erpobdella octoculata, E. testacea, Trocheta bykowskii*).

5.4.114 Many of the results that identify certain taxa as being negatively or positively associated with low DO or DO events below given thresholds are consistent with published data on pollution sensitivity of invertebrates. The mayfly Caenidae has a relatively high BMWP (pollution sensitivity) score, although some studies show that it is less sensitive to increased organic loads than other mayfly taxa (Walley *et al*, 2001[37]). Likewise, Gammaridae and Neritidae are generally more sensitive to increased organic loads (Walley and Hawkes, 1996[38]; 1997[39], Mouthon 1996[40]) than many Oligochaeta taxa, for example *Tubifex tubifex*, a common and highly pollution worm species in the tidal Thames.

5.4.115 The pea mussels Sphaeridae, which were identified as being positively correlated with low DO, include a wide range of species with varying tolerances to low DO. However, the principal species recorded (for which data were available) included *Pisidium casertanum, Pisidium nitidum* and *Pisidium personatum*, which have been demonstrated to have high tolerances to biodegradable pollution (Mouthon, 1996)[41]. Likewise, Chironomidae have varying tolerances to both low DO and high salinity, but no species level data were provided for the tidal Thames data set.

5.4.116 Seasonal patterns associated with the ecological and biological traits of the different invertebrates are likely to have been influential on their temporal and spatial variation, notably for groups such as insects. However, EA records show that many groups appear to be affected by environmental parameters independently of seasonal patterns. For example, Caenidae were collected consistently in spring samples between 1997 and 2002, but were absent from subsequent samples collected at the same time of year (and sample method) following 'poor' water quality (low DO) periods (such as 2003).

Middle Tideway

5.4.117 The variations in invertebrate assemblages in the Middle Tideway, or brackish zone (Greenwich and Beckton STW sample sites) were dominated by a limited number of taxa, as in the freshwater zone. At Greenwich, the PCA analyses indicated that the greatest variations were between Hydrobiidae, Gammaridae, Cochliopidae (snails), Spionidae (Polychaete worms) and Oligochaeta, with the latter (Oligochaete worms) dominating summer samples.

5.4.118 Although similar patterns were observed at Beckton, variations in abundances of Gammaridae were more significant than at Greenwich, while Cochliopidae contributed less to this variation. RDA (see para. 5.4.102 showed that some invertebrate taxa were shown to be more or less tolerant of poor water quality and/or saline intrusion, and along with habitat preferences is likely to account for differences at the site. Beckton STW discharge is likely to be an important factor, which discharges a constant and significant organic load and freshwater flow into a more saline area of the tidal Thames. The water is therefore locally less saline and frequently deoxygenated at the sample site, compared with Greenwich and other nearby sites, which may explain the above differences.

5.4.119 The associations between environmental factors and invertebrate taxa indicate how water chemistry influences the invertebrate community at Greenwich, as illustrated by the RDA. Again, it is difficult to discriminate between the influence of poor water quality (such as DO sags) and the effects of salinity, as they both tend to occur at the same time (during hot and dry periods of low freshwater flows). However, a number of the taxa apparently impacted by low DO are known to be highly tolerant to variations in salinity, notably the species of Clavidae, Corophiidae (Queiroga, 1990)[42] (Mills and Fish, 1980)[43], Sphaeromatidae (isopods), Hydrobiidae (Gerard *et al*, 2003)[44] and Anthuridae (isopods) and the Gammaridae (Bulheim and Scholl, 1981)[45] (Bulheim, 1979)[46] (*G. zaddachi* or *Gammarus salinis* in some years) were present.

5.4.120 As at other sites, a number of invertebrates were positively correlated with low DO, notably Cochliopidae, Nereidae (Polychaete worms), Cirratulidae (Polychaete worms), Spionidae and Oligochaeta worms. This is fairly consistent with scientific research, which suggest that these taxa are tolerant to organically enriched and low DO environments. For example *Hediste diversicolor* (the species of Nereidae present) is a euryhaline species that inhabits littoral muds and sands that have lower oxygen levels than other sediments. *Hediste diversicolor* is resistant to moderate hypoxia (Diaz and Rosenberg, 1995)[47] and smothering by silt (Jones *et al*, 2000)[48]. Likewise, although there are inconsistencies in the data set and different species of Cirratulidae and Spionidae, both of these groups have been shown as indicators of a stressed community due to pollution in marine environments (Bailey-Brock *et al*, 2020[49]; Bryan, 1984[50]; Dean, 2008[51]).

5.4.121 There are, however, some differences between the reactions of the Greenwich community to low DO and the reactions of communities at other sites. For example Hydrobiidae were shown as being sensitive to low DO events, although at upstream sites the same species (*P. antipodarum*) was tolerant. There are a number of possible biological explanations, such as varying DO tolerance in different levels of salinity (the species is tolerant to a broad range of salinity concentrations) or the presence of hypoxia tolerant ‘strains’. Another more simple reason is that in the lower tidal Thames, DO drops more frequently, for longer periods and at different periods in the year compared with upstream, which may exert greater or differing pressures on this species.

5.4.122 The RDA of the Beckton sample site showed that the environmental variables explained a much lower proportion (15.8%) of the invertebrate variations observed compared with all other sites. Although clear relationships with freshwater flow at Teddington have been demonstrated, there are also a number of anomalies compared with other sites and DO concentrations and/or events do not clearly and consistently explain the invertebrate assemblages recorded. For example, a number of taxa appear to be negatively correlated with both low DO events (frequency/duration of events less than < 1.5 mg/L and/or < 3 mg/L) and high mean DO concentrations. It is likely that elements associated with Beckton STW discharge is highly important and ‘confusing’ the analysis. This has not been included in this investigation as data were not readily available and this assessment was outside the scope of this investigation. Moreover, water quality data were taken from two different sites near to Beckton, which may have somewhat localised differences in DO and other variables.

5.4.123 It is also important to point out that the invertebrate community at Beckton is the most impoverished of all sample sites, in terms of invertebrate diversity. In a study of this site on the Thames, Attrill (1998)[52] found that this site had the lowest numbers of species, with low numbers of a single species or no animals at all frequently recorded, despite having similar sediment characteristics to other nearby sites (such as Woolwich), which had higher abundances and invertebrate diversity. Because of this, results from this site need to be considered with prudence.

The presence of rare and notable species

5.4.124 The Community Conservation Index (CCI) score (Chadd and Extence, 2004)[53] has been used to assess whether any species of nature conservation importance are present. CCI classifies many groups of invertebrates of inland waters according to their scarcity and conservation value in Great Britain. The scores range from 1 to 10, with 1 being very common and 10 being endangered, relating closely to the Red Data Book (RDB) (Bratton, 1991)[54] ; (Shirt, 1987)[55].

5.4.125 Most of the tidal Thames is characterised by species of low or moderate conservation importance and low CCI scores (5 or less). Species of conservation importance are presented in Vol 3 Table 5.4.7. Tentacled lagoon worm (*Alkmaria romijnii*) is the only species which receives statutory protection. It has been recorded on several occasions between Woolwich and Crossness. One CCI 10 (Endangered) species occurs in the Barking Creek, whilst a further three species score 9 (Vulnerable) (*Ephemera lineata, Stenelmis canaliculata, Valvata macrostoma).* All of these are freshwater species which occur close to the tidal limit at Teddington.

5.4.126 *A. lacustre* is an RDB 2 species and scores CCI 8. However, EA data have shown that is common in the tidal Thames and its distribution appears to have increased since it was classified. It is typically a brackish species that tolerates near freshwaters (Lincoln, 1979)[56].

Vol 3 Table 5.4.7 Aquatic ecology – rare and notable invertebrate species

Species	Group	Rarity status/Importance	Occurrence within study area	CCI SCORE	EA data set?
Ephemera lineata	Mayfly	RDB 2 (UK)	Teddington Lock	CCI 9 (vulnerable)	No
Stenelmis canaliculata	River beetle	RDB 2 (UK)	Teddington Lock	CCI 9 (vulnerable)	No
Valvata macrostoma	Large-mouthed valve snail	RDB 2(UK)	Teddington Lock	CCI 9 (vulnerable)	No
Batracobdella paludosa	Leech	Metropolitan	Isleworth EA data set, recorded at Barnes in 1 sample in 2005 (4 individuals recorded)	CCI 7 (notable but not RDB status)	Yes
Trocheta bykowskii	Leech	District	Isleworth, Kew	CCI 5 (local)	No
Ecnomus tenellus	Caddis fly	Local	Teddington, Kew	CCI 5 (local)	No
Tentacled Lagoon Worm *(Alkmaria romijnii)*	Worm	Schedule 5 of Wildlife & Countryside Act 1981 (as amended) Nationally Scarce in UK	Woolwich	No designated CCI for Polychaeta in listing	No
Swollen Spire Snail Mercuria (Pseudamnicola) confusa	Snail	RDB species	Previously recorded in Barking Creek, which is part of the tidal excursion area of Crossness. Not on the tidal Thames	CCI 10 (endangered)	No
Apocorophium lacustre	Mud	RDB (3) species, red,	Abundant throughout the	CCI 8 (rare)	Yes

Species	Group	Rarity status/Importance	Occurrence within study area	CCI SCORE	EA data set?
	shrimp	based on pre-1994 red list GB	tideway, most abundant further downstream		
Pisidium pseudosphaerium	Pea mussel	RDB 3, IUCN red list of threatened species	EA data set, recorded at Barnes in 1 sample in 2005 (5 individuals recorded)	CCI 8 (rare)	Yes
Pseudanodonta complanata	Depressed river mussel	UK BAP Priority species, IUCN red list of threatened species	Richmond	CCI 7 (notable)	No
Pseudotrichia rubiginosa	German hairy snail	RDB 3 species, IUCN red list of threatened species	Previously recorded at Richmond, Hounslow, Newham and Barking and Dagenham Occurs along the water line.	No designated CCI	No
Balea biplicata	Two lipped door snail	RDB 3 species	Previously recorded at sites in Richmond and Hounslow. Occurs along the water line.	No designated CCI	No

Distribution of alien and invasive species

5.4.127 The key invasive species recorded during surveys in 2010 and 2011 included:

a. Zebra mussel (*Dreissena polymorpha*)

b. Asian clam (*Corbicula fluminea*)

c. Chinese mitten crab (*Eriocheir sinensis*).

5.4.128 The zebra mussel can establish in densities that crowd out native invertebrates and also colonises shells of native species, reducing the ability of the host to feed and burrow. Asian clams can also reach high densities, consuming significant amounts of phytoplankton. In certain environments the increased water clarity caused by their filtration can lead to increases in light penetration, enhanced macrophyte growth, and alteration of fish stocks, although this is unlikely to be the case in the relatively turbid environment of the tidal Thames. Further, the Asian clam may also alter the benthic substrate (Elliott and zu Ermgassen, 2008)[57]. Zebra mussel and Asian clams appear to be mostly limited to more upstream areas of the tidal Thames (upstream of Chelsea Embankment Foreshore).

Vol 3 Plate 5.4.16 Aquatic ecology - Radix balthica (left) and Asiatic clam (right)

5.4.129 Mitten crabs cause bank destabilisation and erosion, and also compete for food resources with other species. The former issue is less of a concern at this location as much of the river bank comprises hard defences, but competition with other species could occur. Mitten crabs have been collected in samples throughout the area of the tidal Thames considered in this investigation (from Beckton to Kew), reflecting their migratory behaviour.

Vol 3 Plate 5.4.17 Aquatic ecology - Chinese mitten crab

Summary and evaluation

5.4.130 The invertebrate community of the tidal Thames is characteristic of an estuary, with a transition from freshwater taxa in the Upper Tideway to brackish and marine communities in the lower reaches. The invertebrate community is considered to be of medium-high (metropolitan) importance due to the range of protected and notable species, but the relative importance of the community as a whole.

Algae

5.4.131 This section presents a summary of the baseline information relating to algae within the study area. The available baseline data consists of previous studies undertaken by ecologists at the Natural History Museum (NHM) and data collected specifically for the Thames Tideway Tunnel project. Baseline algal surveys were undertaken during June 2012 at Thames Tideway Tunnel project foreshore sites.

5.4.132 This section aims to present an overview of the algal community in terms of its composition and the distribution of species. Where possible, any trends in the composition of the algal community over time are highlighted based on the NHM background dataset.

5.4.133 Raw data and more detailed analysis is provided in the baseline report (Vol 3 Appendix C.1). Specifically, the following section focuses on four main areas;

a. A summary of the 2012 algal survey data.

b. An overview of algal community composition and its change with distance through the tidal Thames

c. The presence of rare and notable species

d. The nature and range of notable habitats for algae through the tidal Thames

5.4.134 Algae occurs in the tidal Thames both in the water column (pelagic) and growing on the river wall and associated structures. The range of species which occur in the tidal Thames reflect both salinity, habitat and environmental conditions. As well as their intrinsic value algal communities provide valuable habitat for invertebrates and juvenile fish. Algae are often used as an indicator of water quality, since nutrients associated with sewage promote the growth of certain species of algae. This assessment focuses on the algal communities which grow on the river wall and associated structures.

Baseline surveys

5.4.135 Algal surveys of the river walls at eight foreshore sites along the tidal Thames were undertaken during 2012, following methodology outlined in Vol 2 Section 5. The sites surveyed were: Putney Embankment Foreshore; Heathwall Pumping Station; Chelsea Embankment Foreshore; Albert Embankment Foreshore; Victoria Embankment Foreshore; Blackfriars Bridge Foreshore; Chambers Wharf; and King Edward Memorial Park Foreshore.

5.4.136 Riparian algal vegetation was recorded at all sites investigated (Vol 3 Table 5.4.8). The algal cover extended vertically from high tide level to lower levels, in many cases the foot of the wall. The algal vegetation was mostly Chlorophyta (green algae) that showed as a distinct green band. The predominant species in the river from King Edward Memorial Park Foreshore to Chelsea Embankment Foreshore were *Blidingia marginata* and *Blidingia minima*, thus characterising a distinct community. Altogether 13 species of Chlorophyta, Xanthophyceae (yellow-green algae) and Rhodophyta (red algae) were identified. In addition to macroalgae, micro algae - diatoms were commonly present either as epiphytes, or silt-binding on the walls, sometimes as a zone at lower levels. One species, the non-native *Hydrosera triquetra*, grew among green algae but at Victoria Embankment Foreshore formed a distinct zone at low levels on the wall and steps. Cyanobacteria (formerly blue-green algae) were also commonly occurring among macroalgae or silt-binding on river walls.

Vol 3 Plate 5.4.18 Aquatic ecology - *Blidingia minima* zone at Westminster

Vol 3 Table 5.4.8 Aquatic ecology – algae recorded during surveys of river walls during June 2012

Species	KEMP	Chambers Wharf	Blackfriars Bridge Foreshore	Victoria Embankment Foreshore	Albert Embankment Foreshore	Chelsea Embankment Foreshore	Heathwall Pumping Station	Putney Embankment Foreshore
Blidingia marginata	Y	Y	Y	Y	Y	N	Y	N
Blidingia minima	Y	Y	Y	Y	Y	Y	Y	Y
Cladophora glomerata	Y	N	Y	Y	Y	Y	Y	Y
Rhizoclonium riparium	Y	Y	Y	Y	Y	Y	Y	Y
Ulothrix flacca	N	N	N	N	N	N	Y	N
Ulva compressa	Y	Y	N	N	N	N	N	N
Ulva prolifera	N	Y	N	Y	Y	Y	Y	Y
Urospora penicilliformis	N	N	N	N	Y	N	N	N
Vaucheria sp.	Y	Y	Y	Y	Y	Y	Y	Y
Bangia atropurpurea	N	N	N	Y	Y	Y	N	N
Polysiphonia stricta	N	Y	N	N	N	N	N	N
Rhodochorton purpureum	N	Y	N	N	N	N	N	N

5.4.137 Both *Blidingia* species occur widely in Britain at upper littoral and supralittoral levels, and also just above the waterline on floating structures; they are common fouling species. In this section of the tidal river, both species occur more widely in the upper littoral, ie, from midlittoral to supralittoral fringe levels. *B. minima* occurred more commonly than *B. marginata* and was more abundant in insulated situations than in shade. Both are often the only species on harder, drier concrete, and elsewhere on also sheet metal piling; *Blidingia* spp. are thus likely to colonise temporary structures built into the river.

5.4.138 *Rhizoclonium riparium* occurred widely and commonly on river walls studied; it was present at the eight sites studied but at three, all north-facing and less insulated and of brick, formed distinct communities and zones. The zones were more extensive at Albert Embankment Foreshore and Putney Embankment Foreshore where the river's salinity was lower. On south-facing walls *Rhizoclonium* occurred among a mat of *Blidingia* spp. and was more noticeably present at Chelsea Embankment Foreshore. *Rhizoclonium riparium* is a widely occurring species in Britain at upper littoral levels.

5.4.139 The dark-green branched (often unbranched in the tidal Thames) filamentous *Cladophora glomerata* was recorded at the eight sites studied, and at two (Blackfriars Bridge Foreshore, Chelsea Embankment Foreshore) formed a zone at the foot of the wall; at other sites (King Edward Memorial Park Foreshore, Victoria Embankment Foreshore) it was patchily present and at the remaining sites occurred among the macroalgal turf on the lower parts of walls. *Cladophora glomerata* is a widely occurring freshwater species that also occurs in low salinity brackish habitats as in the present study area (Tittley, 2009)[58].

5.4.140 Despite a long history of being recorded in the tidal Thames (Tittley, 2009)[59] the tubular *Ulva* (*Enteromorpha*) spp. were only scantly found in the present survey although noted for seven out of the eight sites studied. Two species were identified, *Ulva compressa*, *Ulva prolifera*, which grew among the mat of macroalgae on the river walls. These occur widely in Britain in saltmarshes and estuaries as well as on open shores, and particularly commonly in eutrophicated situations.

5.4.141 Other green algae recorded were *Ulothrix flacca* and *Urospora penicilliformis*; both were only scantly recorded in this section of the tidal Thames.

5.4.142 The yellow-green alga (Ochrophyta, Xanthophyceae) *Vaucheria* (probably *compacta*) sp. was recorded at the eight sites studied. It was more noticeably present on the north facing brick walls at Chambers Wharf and Putney Embankment Foreshore. The species has been long-known in the tidal Thames.

5.4.143 Red algae occur rarely in low salinity estuaries being largely restricted to marine outer estuarine reaches and sea-shores; three species were recorded in the present survey. *Bangia atropurpurea* occurred at three sites and at two (north-facing brick walls) formed putative narrow bands near the foot of the wall at approximately mid tide level. Unusually for red algae, *Bangia atropurpurea* is a species that occurs in fresh, brackish and marine conditions. The filamentous *Rhodochorton purpureum* was recorded as velvety red growth in shaded situations at high tide level on brick very close to the existing jetty at Chambers Wharf. *Rhodochorton purpureum* occurs commonly in caves on open sea shores and is not uncommon in low salinity situations. The filamentous *Polysiphonia stricta* was found, rarely occurring among macroalgae on the brick wall at Chambers Wharf. Some forms of this species have been found in low salinity environments elsewhere (Tittley, 2001[60], Tittley 2009[61]). All other representatives of this genus are fully marine species. The discovery of *P. stricta* and *R. purpureum* represents an extension in their distributional range in the tidal river and their currently known maximum upriver penetrations.

5.4.144 Data was received from the NHM that identifies records of marine algae received for the period from the early 1970s to 1999. Records are shown in Vol 3 Table 5.4.9.

Vol 3 Table 5.4.9 Aquatic ecology – marine algae sampled in the tidal Thames between early 1970s and 1999

Species	Putney Embankment Foreshore	Chelsea Embankment Foreshore	Albert Embankment Foreshore	Cleopatra's Needle	Wapping	KEMP	Deptford Creek
Blidingia marginata	Y	Y	Y	Y	Y	Y	Y
Blidingia minima	Y	Y	Y	Y	N	Y	Y
Cladophora glomerata	N	Y	Y	N	N	Y	N
Rhizoclonium riparium	Y	Y	Y	Y	Y	Y	Y
Ulothrix flacca	N	Y	N	N	N	N	N
Ulva compressa	N	N	N	N	N	Y	N
Ulva prolifera	N	Y	Y	N	N	N	Y
Urospora penicilliformis	Y	N	Y	N	N	Y	Y
Vaucheria sp.	N	Y	Y	Y	N	N	N
Bangia atropurpurea	N	N	Y	N	N	N	N
Polysiphonia stricta	N	N	N	N	N	N	N
Rhodochorton purpureum	N	N	N	N	Y	Y	N

5.4.145 All other previous surveys agree with the present survey in recording the dominance of green in the London reaches of the tidal Thames. The predominance of *Blidingia* spp. was recorded previously at Woolwich, Thames Barrier, Charlton, Deptford Creek, and Wapping Police Jetty (Tittley, 1985)[62], (Cox and Tittley, 2000) [63], (Tittley and Cox, 1997) [64] where quantitative studies were undertaken. Previous qualitative studies also revealed the predominance of green algae.

5.4.146 Present and past surveys showed the decrease in species richness upriver with the decrease in salinity.

5.4.147 Previously, *R. purpureum* and *P. stricta* were recorded in shaded situations at Woolwich, the former also at Charlton (Tittley, 2009)[65] in similar circumstances to their occurrence on the brick wall at Chambers Wharf. *B. atropurpurea*, recorded at Wapping Police Jetty in shade on brick occurred in a similar habitat on the other side of the river at Chambers Wharf. The predominance of *R. riparium* and *R. purpureum* in more shaded situations in the present survey agrees with the conclusions of previous studies that showed this by numerical analysis of quadrat data. Several species (*Porphyridium purpureum*, *Pseudendoclonium submarinum*, *Pylaiella littoralis, Ulvaria oxysperma*) were recorded at Woolwich (Tittley, 2009)[66] but not seen in the present survey. Reasons for these vary from simply overlooked (the 2012 survey was undertaken at only one point in time), intolerance of very low salinity, or seasonal occurrence.

The presence of rare and notable species

5.4.148 No rare or notable species were recorded from the tidal Thames during surveys undertaken in 2012, or were noted in records obtained from relevant locations since the 1970s.

Summary and evaluation

5.4.149 A macroalgal flora typical of a low salinity tidal environment was recorded in the tidal Thames with a decrease in diversity toward the freshwater reaches at Putney Embankment Foreshore. The algal community is considered to be of medium (borough) importance due to the limited range of common species present.

Summary of receptors

5.4.150 Vol 3 Table 5.4.10 presents a summary of the receptors identified and their values/sensitivities.

Vol 3 Table 5.4.10 Aquatic ecology – summary of receptors and their values/sensitivities

Receptor	Value/sensitivity
Designated sites	High (International) - Thames Estuary and Marshes SPA High (National) – Inner Thames Marshes SSSI, Syon Park SSSI, Barn Elms Wetland SSSI Medium-high (Metropolitan) – River Thames and Tidal Tributaries SINC (Grade M), Lavender Pond LNR, Dukes Hollow LNR, Leg of Mutton Reservoir LNR, Chiswick Ayot LNR, Isleworth Air/Ayot LNR. Medium (Borough) – Beverley Brook SINC (Grade

Receptor	Value/sensitivity
	B)
Habitats	Medium-high (Metropolitan).
Mammals	High (Regional)
Fish	High (Regional)
Invertebrates	Medium-high (Metropolitan)
Algae	Medium (Borough)

Construction base case

5.4.151 The base case in Site Year 1 of construction would include the improvements at the five main sewage treatment works that discharge into the tidal Thames (Mogden, Beckton, Crossness, Long Reach and Riverside), and the Lee Tunnel. TFRM modelling (Vol 3 Appendix C.3) has shown that at a river wide level there will be a significant reduction in the occurrence of mass or population level fish mortalities with these schemes (i.e. hypoxia events, which result in more than 10% mortality of fish populations). However, predictions for the base case show that, even with these schemes, unsustainable mortalities of salmon, the most sensitive species can be expected. Salmon is considered as acting as a surrogate for the more sensitive aspects of ecology, and thus taxa other than salmon may also be harmed under this condition.

5.4.152 For example, although the TFRM shows that adult smelt populations will be sustainable, recent research shows that juveniles of this species have a lower tolerance to hypoxia and therefore are likely to exhibit a higher level of mortality.

5.4.153 Given that CSOs within the tidal Thames would continue to spill, and no significant changes in habitat quality are anticipated existing conditions for fish may be expected to support a similar assemblage of species to the current baseline, with potentially a greater number of pollution sensitive species and life stages. Recovery due to water quality improvements will, however, be at an early stage.

5.4.154 The invertebrate analysis demonstrates that more pollution sensitive groups such as shrimps (Gammaridae) are subject to significant fluctuations in abundances during low DO periods. With the improvements associated with the Lee Tunnel scheme and sewage treatment works upgrades at Mogden, these fluctuations are likely to be reduced. Whilst there may be minor changes, increases in abundance and diversity will however be limited by the fact that even with the Lee Tunnel and STW improvements in place there are still predicted to be numerous failures of DO standards. Colonisation by DO sensitive taxa such as Corophiidae, Crangonidae and Gammaridae which would otherwise occur within the brackish zone, including Blackfriars Bridge Foreshore would continue to be suppressed. As for fish, recovery of the invertebrate communities would be at an early stage. The recovery in algal communities that has taken place since the 1960s is expected to continue under the base case, however the baseline conditions are not anticipated to significantly change from that described in paras. 5.4.131 to 5.4.148 . No changes in marine mammals are anticipated as they are relatively insensitive to point source sewage discharges.

5.4.155 There is unlikely to be encroachment onto the River Thames foreshore for non-river dependent uses as this is restricted through *London Plan 2011* (GLA, 2012)[67] Policy 7.28 Restoration of the Blue Ribbon Network which states that development should 'protect the value of the foreshore of the Thames and tidal rivers'. The EA's *National Encroachment Policy for Tidal Rivers and Estuaries* (Environment Agency, 2005)[68] also presumes against developments riverward of the existing flood defences where these would, individually or cumulatively, change flows so that fisheries were affected or cause loss or damage to habitat. Therefore no change to current baseline from other developments is considered likely.

Operational base case

5.4.156 The river wide recovery in fish and invertebrate communities that will occur as a result of the Lee Tunnel and sewage treatment works upgrades will have advanced by Year 1 and Year 6 due to the reduced number of hypoxia events. However, as noted in para. 5.4.151 there will still be unsustainable mortalities of salmon, and possibly other sensitive taxa. Further, catchment modelling shows that the frequency, duration and volume of spills from the CSOs will continue to rise due to population growth, which will limit improvements for aquatic ecology receptors (spill frequency and volume as stated in para. 5.2.23. Further details of spills are provided in Section 14 of this volume). Therefore recovery due to water quality improvements will be suppressed at the CSO locations. As a result there are unlikely to be significant changes in habitat quality and pollution sensitive fish species, such as salmon will continue to be suppressed. Indeed, conditions in the immediate vicinity of the CSOs may be less favourable for fish than the current baseline given the increase in frequency, volume and duration of CSO spills. At a river wide scale invertebrate communities will include more pollution sensitive components as noted in para. 5.4.153 - 5.4.154. However, increased CSO spill frequency, durations and volumes will suppress recovery and may also be less favourable than current baseline conditions given the increase in frequency, volume and duration of CSO spills.

5.4.157 The recovery in algal communities that has taken place since the 1960s is expected to continue under the base case however the baseline conditions are not anticipated to significantly change from that described in paras. 5.4.131 to 5.4.148 . No changes in marine mammals are anticipated as they are relatively insensitive to point source sewage discharges.

5.4.158 As stated in para. 5.4.155 there is unlikely to be encroachment onto the tidal Thames foreshore for non-river dependent uses. Therefore no change to current baseline from other developments is considered likely.

5.5 Construction effects assessment

Construction impacts

Temporary landtake

5.5.1 There would be temporary landtake from intertidal and subtidal habitats at each of the eleven sites where construction would take place on the foreshore. Temporary landtake would result from the construction of cofferdams, campsheds and other in river facilities such as jetties.

5.5.2 There would be dredging of the areas occupied by the campsheds at Carnwath Road Riverside, Kirtling Street and associated with the relocated Millennium Pier location at Blackfriars Bridge Foreshore. The timing and methods used for dredging would be subject to the controls described in 5.2.18i

5.5.3 The relative losses from intertidal and subtidal habitats at each site is presented in Vol 3 Table 5.5.1. In total there would be landtake of 2.2ha from intertidal habitats and 1.2 from subtidal habitats. This represents 0.15% of the River Thames and Tidal Tributaries SINC (Grade M) and 0.46% of the intertidal and 0.08% of the subtidal habitats within this SINC.

Vol 3 Table 5.5.1 Aquatic ecology – temporary landtake from sites with construction works on the tidal Thames foreshore

<table>
<tr><th>Thames Tideway Tunnel project site</th><th>Area of temporary landtake (m2) from intertidal habitat</th><th>Area of temporary landtake (m2) from subtidal habitat</th><th>Area as percentage of SINC (Upper or Middle Tideway zone in brackets)</th></tr>
<tr><td>Putney Embankment Foreshore</td><td>2985</td><td>450</td><td>0.01
(Upper = 0.06)</td></tr>
<tr><td>Carnwath Road Riverside</td><td></td><td></td><td></td></tr>
<tr><td>Option A</td><td>2160</td><td>0</td><td rowspan="2">0.01
(Upper = 0.06)</td></tr>
<tr><td>Option B</td><td>50</td><td>2160</td></tr>
<tr><td>Chelsea Embankment Foreshore</td><td>3250</td><td>485</td><td>0.02
(Upper = 0.07)</td></tr>
<tr><td>Kirtling Street</td><td>0</td><td>50</td><td><0.001</td></tr>
<tr><td>Heathwall Pumping Station</td><td>600</td><td>35</td><td>0.003
(Upper = 0.01)</td></tr>
<tr><td>Albert Embankment Foreshore</td><td>6385</td><td>580</td><td>0.03
(Middle = 0.04)</td></tr>
<tr><td>Victoria Embankment</td><td>0</td><td>2695</td><td>0.01
(Middle = 0.05)</td></tr>
</table>

Thames Tideway Tunnel project site	Area of temporary landtake (m2) from intertidal habitat	Area of temporary landtake (m2) from subtidal habitat	Area as percentage of SINC (Upper or Middle Tideway zone in brackets)
Foreshore			
Blackfriars Bridge Foreshore	275	2105	0.01 (Middle = 0.01)
Chambers Wharf	4890	3625	0.04 (Middle = 0.05)
King Edward Memorial Park Foreshore	250	2175	0.01 (Middle = 0.01)
TOTAL	**21790**	**12200**	**0.15**

5.5.4 Foreshore construction sites would be in place for a maximum period of six years. The construction of the temporary cofferdams would involve re-profiling of the existing foreshore (see para. 5.2.7). Reinstatement would involve the removal of imported granular fill and the geotextile membrane and the placement of imported substrate in order to restore the area to a similar profile of the surrounding foreshore. The imported substrate material would replicate the existing foreshore particle size. The approach to foreshore reinstatement is described in Vol 3 Appendix C.4.

5.5.5 Recovery of these sites is likely to take between one and five years, and may thus be considered a medium negative impact based on Vol 2 Section 5.5. However, the extent of the areas affected (0.15% of the SINC) in the context of the overall size of the Upper and Middle Tideway is small. On this basis, the impact of temporary landtake is considered to be low negative. The probability of the impact occurring is considered to be 'certain.'

Sediment disturbance and consolidation

5.5.6 It has been assumed that the area between the outer edge of the cofferdams and the maximum extent of working area at all sites would be subject to disturbance and consolidation. These impacts would arise at foreshore construction sites due to the presence of jack up barges or similar to install temporary cofferdams.

5.5.7 The area affected by disturbance and compaction varies from 3240m^2 at King Edward Memorial Park to 25562m^2 at Blackfriars Bridge Foreshore. The total area affected is 133000m^2, which equates to 0.58% of the SINC. In terms of subtidal habitat within the SINC, 99,153m^2 represents 0.6% of this habitat within the SINC, whilst 33,880m^2 of intertidal area affected represents 0.6% of this habitat within the SINC. Areas subject to sediment disturbance and consolidation are presented in Vol 3 Table 5.5.2

Vol 3 Table 5.5.2 Aquatic ecology – disturbance and consolidation at sites with construction works on the tidal Thames foreshore

Thames Tideway Tunnel project site	Maximum area of disturbance and consolidation (m2) from intertidal habitat	Maximum area of disturbance and consolidation (m2) from subtidal habitat	Area as percentage of SINC (Upper or Middle Tideway zone in brackets)
Putney Embankment Foreshore	8430	9635	0.08 (Upper = 0.3)
Carnwath Road Riverside	3880	10980	0.06 (Upper = 0.3)
Chelsea Embankment Foreshore	4635	7570	0.05 (Upper = 0.2)
Kirtling Street	3670	18320	0.1 (Upper = 0.4)
Heathwall Pumping Station	2955	4340	0.03 (Upper = 0.1)
Albert Embankment Foreshore	6450	9480	0.07 (Middle = 0.09)
Victoria Embankment Foreshore	55	8050	0.04 (Middle = 0.05)
Blackfriars Bridge Foreshore	1730	23830	0.11 (Middle = 0.1)
Chambers Wharf	1140	4640	0.03 (Middle = 0.03)
King Edward Memorial Park Foreshore	940	2300	0.01 (Middle = 0.02)
TOTAL	33885	99145	0.58

5.5.8 The impact would take place primarily during the site establishment stage as jack up barges are being used as a platform from which to install sheet piling for the cofferdams. Recovery of areas affected by disturbance and compaction is expected to take place within 1 to 5 years of completion of the site establishment stage. The impact is thus considered to be low negative because although recovery is likely to take 1 to 5 years, the affected area is small in the context of the overall size of the SINC. The probability of the impact occurring is considered to be 'certain.'

Change to scour patterns

5.5.9 Modelling studies have been undertaken to predict the extent and nature of any scour associated with the temporary structures. The scour prediction studies have employed 2D mathematical modelling and physical scale models, informed by grab sampling and boreholes within the river, in order to understand patterns and magnitudes of scour at each of the Thames Tideway Tunnel project foreshore sites[69]. The modelling studies are described in detail in *Fluvial Scour Study Peer Review* (Black and Veatch, 2012)[70]. A summary of the results as they relate to relevant aquatic ecology receptors (i.e. habitats and fish) is provided below.

5.5.10 The overall analysis of scour at eight foreshore sites modelled indicates that scour would occur locally around temporary structures such as cofferdams and campsheds (abutment scour), as well as within the main river channel (contraction scour) due to increased flow velocities caused by channel constriction.

5.5.11 Predicted abutment scour ranges in depth from 0.3m at Victoria Embankment Foreshore to 2.5m at Putney Embankment Foreshore. Contraction scour has been calculated as being less than 0.1m at all of the foreshore sites. These scour predictions are based on known substrate type (measured as particle size) and bed strength information at each site.

5.5.12 No mitigation (in the form of scour protection measures) is proposed to offset temporary scour effects arising from the temporary works, although sites would be monitored and scour protection measures implemented if scour levels exceed a limit which would have been agreed with relevant stakeholders. Further details are provided in *Scour monitoring and mitigation strategy* (Vol 3 Appendix L.4). Localised areas around temporary structures may be subject to accretion rather than scour, but increases in flow velocities generally would be expected to result in a net increase in sediment released into the water column. Contraction scour alone is predicted to lead to a potential increase in 1600t of sediment release during the construction phase (Section 14 of this volume).

5.5.13 Scour events are likely to give rise to sudden increases in suspended sediment, which have an impact on water quality. These are discussed in paras. 5.5.23 to 5.5.26.

5.5.14 The impact of the change to the hydrodynamic regime (in terms of scour and flow velocity) is considered to be low negative, probable and temporary.

Changes to the hydraulic regime

5.5.15 In addition to scour changes in flow, velocities in the vicinity of the temporary works may affect the ability of smaller, weakly swimming fish (mainly juveniles) to remain in habitat within the hydraulic footprint of the construction area or to move past the structure.

5.5.16 The modelling studies indicate that flow velocities would increase particularly around the outer corners of the temporary structures. However, lower velocities would also occur in the lee of the structures thus providing refuges for pelagic species of fish and invertebrates.

5.5.17 Overall, the impact of the change to the hydraulic regime as a result of the temporary structures is considered to be negligible, probable and temporary.

Waterborne noise and vibration

5.5.18 The installation of the cofferdams at the foreshore construction sites has the potential to generate waterborne noise and vibration. Piles would be driven using vibro piling techniques, thus limiting the principal source of waterborne noise and vibration impacts. Further measures to limit noise and vibration impacts during the construction stage have been incorporated into the *CoCP Part A* (Section 6). These are described in para. 5.2.18.

5.5.19 Nedwell and Edwards (2002)[71] report that vibro-piling in the River Arun associated with construction of a quay wall produced underwater sound pressure levels of 132-152 dBre1µPa[ii] at distances of between 16m and 82m from the source (the variation in sound level was not attributable to distance since the highest sound levels were recorded at the greatest distance, but were instead attributed to variations in soil/sediment density).

5.5.20 There would be additional sources of noise and vibration, including activities associated with construction of the works and vehicle and barge movements.

5.5.21 Vol 3 Table 5.5.3 [72] shows examples of the underwater sound pressure levels at source (i.e. at 1m) of various marine vessels.

Vol 3 Table 5.5.3 Aquatic ecology – noise levels of marine vessels

Noise source	dBre1µPa[ii]	kHz
Rigid inflatable	152	6.3
7m outboard motor	156	0.63
Fishing boat	151	0.25-1.0
Tug pulling empty barge	166	0.037
	164	1
	145	5

[ii] This unit is used to measure underwater noise or pressure levels. The measured pressure in decibels (dB) is expressed as a ration against a reference pressure (typically one micro Pascal or 1µPa) and is often written as dBre1µPa, where the “re” means “referenced to” whichever reference value is then described.

Noise source	dBre1μPa[ii]	kHz
Tug pulling loaded barge	170	1
	161	5
34m twin engine diesel workboat	159	0.63
Tanker (135m)	159	0.43
Tanker (179m)	169	0.06
Supertanker (340m)	190	0.007

5.5.22 Although background levels of noise and vibration within the tidal Thames are likely to be moderately high due to existing boat movements, and ground-propagated noise from transport systems, the proximity of the works to the river and their scale and duration means that underwater noise and vibration levels are likely to be elevated locally during construction. This is considered to be a low negative impact, probable and temporary.

Increase in suspended sediment loads

5.5.23 In-river construction activities, including dredging and barge movements, are likely to lead to localised increases in suspended sediment and accretion with the potential to affect habitats locally and more widely within the tidal Thames. Scour processes, described in paras. 5.5.9 to 5.5.15, are predicted to result in the release of sediment, with contraction scour, predicted to cause the most sediment mobilisation. Combining the modelled scour depth with the modelled area of influence gives an estimated 1,600t of fine sediment which could be released by contraction scour.

5.5.24 Modelling (HR Wallingford 2011)[73] suggests 1,400 tonnes of fine sediment may be released into the water column during the construction period (up to six years). A total of 10,700t of fine sediment could be released from the proposed development, as a worst case modelling-based estimate, which could result in an adverse impact on water quality.

5.5.25 In comparison to the existing sediment levels within the tidal Thames, which have been estimated to reach a peak mobilisation of 4000kg released per second or 40,000t in each tide (HR Wallingford, 2011)[74] the release of 10,700t over the six year construction period represents a very small additional input. The potential impact of the release of sediment from the proposed development is therefore considered to be negligible, probable and temporary.

5.5.26 Measures and safeguards to minimise the risk of accidental releases of silty or contaminated discharges to the tidal Thames are included in the *CoCP* Part A (Section 8). These are described in para. 5.2.18i and 5.2.18k. No impacts from polluted discharges are anticipated with these control measures and safeguards in place.

Construction effects

5.5.27 This section describes the effects on aquatic ecology receptors arising from the impacts described in paras. 5.5.1 to 5.5.26 based on the significance criteria set out in Vol 2 Section 2.3.

Designations and habitats

Loss of intertidal and subtidal habitat due to temporary landtake

5.5.28 There would be no temporary landtake from the statutory and non statutory designated sites listed in Vol 3 Table 5.4.1, with the exception of the River Thames and Tidal Tributaries SINC (Grade M). Effects on this non-statutory site are described in para 5.5.30 and 5.5.30. The Acton Storm Tanks CSO discharges adjacent to the Chiswick Ayot. However, the construction site is located inland for this site and no works are proposed at the discharge point.

5.5.29 There would be temporary landtake of around 2.2ha of intertidal habitats and 1.2 ha of subtidal habitats across all of the foreshore sites. This represents approximately 0.15% of the River Thames and Tidal Tributaries SINC (Grade M). The habitats affected by temporary landtake are presented in Vol 3 Table 5.5.1, and include gravel foreshore, intertidal mudflat and subtidal gravels. These habitats, which are considered to be of medium-high (Metropolitan) importance, occur frequently within the tidal Thames.

5.5.30 Once construction works are complete, sites would be restored according to the method outlined in para. 5.2.16 and described in Vol 3 Appendix C.4. The underlying sediment would remain somewhat consolidated until invertebrates burrow back into the sediment and tidal action starts to re-suspend the material, enabling percolation of water into the sediment. Recovery is therefore expected only in the medium (1-5 years) or long term (+5 years). Given that the magnitude of impact is considered to be low negative, the overall effect is considered to be **minor adverse**.

Disturbance and consolidation of intertidal and subtidal habitat

5.5.31 No disturbance or consolidation of intertidal or subtidal habitat is anticipated at any of the statutory or non statutory designated sites listed in Vol 3 Table 5.4.1, with the exception of the River Thames and Tidal Tributaries SINC (Grade M). Effects on this non-statutory site are described in para. 5.5.32 and 5.5.33.

5.5.32 Approximately 3ha of intertidal and 9.3ha of subtidal habitat would be subject to disturbance and consolidation outside the temporary cofferdams. This represents approximately 0.5% of the total area of the River Thames and Tidal Tributaries SINC (Grade M).

5.5.33 The impact would be expected to occur during site establishment phase when the jack up barge is installing cofferdams, and therefore recovery is likely to take place during the remainder of the construction period. Recovery is likely to be take place naturally over a short time (less than 12 months). The overall effect is considered to be **minor adverse**, given the medium-high (metropolitan) value of the receptor and the low negative impact magnitude.

Changes to intertidal and subtidal habitat due to scour and accretion

5.5.34 None of the designated sites listed in Vol 3 Table 5.4.1 would be affected by scour from the temporary works with the exception of the River Thames and Tidal Tributaries SINC (Grade M). In most cases the sites lie outside the main channel of the tidal Thames where scour may be predicted to occur (i.e. Beverley Brook SINC (Grade B), Lavender Pond LNR, Leg of Mutton Reservoir LNR). None of the designated sites which lie within the main channel of the tidal Thames (i.e. Syon Park SSSI, Chiswick Ayot LNR, Isleworth Ayot LNR Dukes Hollow LNR, Thames Estuary and Marshes SPA, Inner Thames Marshes SSSI), lie within the scour zones, identified through modelling, associated with the temporary structures.

5.5.35 There is the potential for accretion of scoured material arising from the temporary works at sites which are hydrologically connected to the tidal Thames. Predictions have been made of the likely effects of accretion on the Thames Estuary and Marshes SPA and are described in further detail in the *Habitats Regulations Assessment: No Significant Effects report,* which accompanies the application. The report concluded that there would be no Likely Significant Effects of the Thames Tideway Tunnel project on any European sites, either alone or in-combination with other projects and plans. The overall effect is thus negligible for the Thames Estuary and Marshes SPA.

5.5.36 The predicted effects of scour and accretion associated with the temporary works could include changes in the nature and extent of intertidal and subtidal habitats within the River Thames and Tidal Tributaries SINC (Grade M). These changes are expected to be temporary, i.e. they would occur for the duration of the construction period, and recovery would take place as a result of natural river processes.

5.5.37 The specific effects of scour at individual sites would be likely to vary according to the nature of the substrate material (measured in terms of grain size) and the magnitude of the predicted increase in velocity, with greater effects anticipated at sites characterised by finer material. At most sites the bed material is dominated by gravel, and predicted scour is not expected to penetrate beyond this superficial gravel layer. On this basis the composition of the habitat (in terms of physical substrate) is not considered likely to change significantly as a result of scour from the temporary works.

5.5.38 However, any fine material, such as sand and silt would be removed from within the scoured areas and is likely to accrete in quiescent areas of the river where accretion currently occurs. Given the predicted volumes of scoured material, these accretion zones are not anticipated to increase significantly in either depth or area.

5.5.39 Heavier particles such as gravel are considered likely to be retained locally in the vicinity of the works, accreting in the quiescent zones immediately up and downstream of the works. These gravel deposits may, at some sites (notably Putney Embankment Foreshore, where relatively higher levels of scour are predicted) form a new habitat feature on the foreshore.

5.5.40 Overall, temporary scour may cause localised changes in the composition and topography of habitats at each of the Thames Tideway Tunnel project sites. The effects would vary between sites and would be most pronounced at Putney Embankment Foreshore where abutment scour depths would be expected to reach a maximum of 2.5m, and minimal at sites such as Victoria Embankment Foreshore (maximum abutment scour of 0.3m).

5.5.41 However, no change in habitat type (i.e. the composition or structure of the broad substrate type or the animals it can support) is anticipated as a result of scour.

5.5.42 The impact of temporary scour at a river wide level is thus considered to be low negative and given the medium-high (metropolitan) value of habitats within the tidal Thames the effect is considered to be **minor adverse**.

Marine mammals

Interference with the migrations of marine mammals within the tidal Thames

5.5.43 Noise, vibration and other construction activity has the potential to disturb mammals and deter them from passing the sites. However, given the use of vibro-piling techniques, impacts are considered to be low negative. Based on research (Nedwell *et al*, 2004)[75] into the hearing thresholds of various marine mammal species, pinniped species including harbour porpoises and grey seal have both been found to be relatively sensitive to noise disturbance. Grey seal was found to have a hearing threshold of around 75dBre1µPa between 5kHz and 50kHz. This is well below the 132-152 dBre1µPa which is likely to occur with vibro-piling at a distances of between 16m and 82m from the source. Hearing thresholds are considerably higher for grey seals in air, i.e. sensitivities are lower when seals are hauled out.

5.5.44 Disturbance arising from construction activity may cause some displacement of pinniped species, particularly in the vicinity of piling operations. However, the frequency of occurrence of these species in the reach of the river affected by construction activity is relatively low. For example, there are generally no more than one or two sightings of seal and harbour porpoise in the vicinity of each of the Thames Tideway Tunnel project sites during the period between 2003 and 2011 when data has been collected by the Zoological Society of London. Furthermore, piling will not be undertaken at night (para 5.2.18b), leaving a clear period for migration.

5.5.45 Based on the significance of effect matrix (Vol 2 Section 5.5) effects may be considered to be moderate adverse, based on a receptor of high (regional) value and a low impact magnitude. However, given the frequency of occurrence of sensitive species such as harbour porpoise and grey seal within the affected zone of the river, and On this basis the effect of noise on mammals has been reduced to **minor adverse**.

Fish

5.5.46 The following section describes the effects on tidal Thames fish populations arising from the impacts occurring during the construction stage. Effects may arise from loss of habitat, noise and vibration, and loss of water column visibility due to suspended sediment. Impacts from the temporary structures on the hydraulic regime of the river may cause scouring of habitats used by fish and also to their migration through the tidal Thames.

Loss of spawning, feeding, resting and nursery habitat for fish due to temporary landtake

5.5.47 There would be potential for the temporary loss of spawning habitat at Putney Embankment Foreshore and Carnwath Road, which lie immediately upstream and within the zone where smelt and dace are known to spawn (the spawning zone is from Wandsworth to Battersea) respectively. The campsheds under option B at Carnwath Road Riverside would lie within the subtidal zone which offers the most suitable spawning habitat for smelt. The effects arising from both options at Carnwath Road Riverside are assessed in full in Vol 10 Section 5. Under option A at Carnwath Road Riverside and at Putney Embankment Foreshore encroachment of the structures into the subtidal zone, which is considered to offer the most suitable spawning habitat, is minimal (Vol 3 Table 5.5.1), and therefore the effects of landtake on spawning habitat are considered to be negligible.

5.5.48 In most cases the foreshore construction sites lie primarily within the shallow intertidal zone of the river, which offers feeding and migratory habitat for juvenile fish. However, the intertidal habitats affected by landtake, are well represented throughout the Upper and Middle Tideway. Temporary landtake represents 0.15% of the area of intertidal and subtidal habitats in the Middle and Upper Tideway. With the exception of option B at Carnwath Road Riverside there would be no landtake from subtidal gravels which are considered to be critical as spawning habitat for smelt and dace.

5.5.49 Assuming option A at Carnwath Road Riverside this magnitude of loss is not considered to affect the overall integrity of the habitat (i.e. its ecological structure and function) or its functionality in supporting the range of fish species that characterise the SINC. Effects on juvenile fish migration are dealt with in paras. 5.5.57 to 5.5.68. Based on the significance of effects matrix (Vol 2 Section 5.5) a low negative impact on a receptor of high (regional) importance gives rise to a moderate adverse effect. However, given that the impact would be temporary, the proportion of loss across the assessment area is minimal and the integrity of the habitat for fish populations is not considered to be affected the overall effect is considered to be **minor adverse**.

5.5.50 With option B at Carnwath Road Riverside there would be a 0.7% temporary loss of smelt spawning habitat. Although a minimal loss this is considered to elevate the level of effect to moderate adverse, since spawning habitat is critical to the sustainability of the fish population.

Loss of feeding, resting and nursery habitat for fish due to sediment disturbance and consolidation

5.5.51 Consolidation of substrate material would result in the total or partial loss of macroinvertebrate communities within the affected area, thus affecting their potential as feeding habitat for fish. The impact would be expected to occur during the site establishment phase when the jack up barge is installing cofferdams, and therefore recovery is likely to take place during the remainder of the construction period. Disturbance and compaction would affect a total area of 123ha, which is equal to 0.5% of the area of the Middle and Upper Tideway.

5.5.52 Based on the importance of the receptor (high (regional)) and the magnitude of the impact (low negative), the effect may be expected to be moderate adverse (Vol 2 Section 5.5). However, given the short duration of the impact (i.e. primarily during the site set up phase), and the availability of alternative habitat effects on feeding, resting and nursery habitat for fish are considered to be **minor adverse**.

Loss of feeding, resting, spawning and nursery habitat due to scour

5.5.53 Scour is expected to cause localised changes in topography and substrate composition in the vicinity of the temporary structures. The loss of fine material such as silt and sand, particularly within the intertidal zone which offers more productive feeding habitat for fish may reduce the suitability of scoured areas for invertebrates, and thus as feeding habitat for fish. However, the scoured areas are sufficiently small that fish would be readily able to find alternative foraging habitat nearby. Scour is not expected to reduce measurably the availability of foraging habitat.

5.5.54 The increased velocities across the width of the channel which lead to contraction scour have the potential to cause wash out of fish eggs from subtidal gravels. This is of particular relevance to smelt and dace which spawn in subtidal gravels between Richmond and Battersea. However, the increases in velocity are not considered to fall outside the range of flows conditions which occur naturally in the river.

5.5.55 Scour has the potential to increase the physical complexity of the bed by creating hollows. Fish may be able to exploit these new habitat features during slack periods of the tide and thus benefit from the effects of scour. However, there is also a risk that scour could remove areas of spawning or feeding habitat.

5.5.56 Based on the importance of the receptor (high (regional)) and the magnitude of the impact (low negative), the effect may be expected to be moderate adverse (Vol 2 Section 5.5). However, given the availability of equivalent feeding, resting, spawning and nursery habitat within the Upper and Middle Tideway, coupled with the potential benefits of increasing the physical complexity of the bed, the overall, the effects of scour are considered to be **minor adverse**.

Interference with the migratory movements of fish

5.5.57 The individual and combined effects on fish of predicted changes in flow velocity associated with the temporary structures have been assessed using an individual based modelling (IBM) technique. Details of the technique and the model outputs are presented in Vol 3 Appendix C.2.

5.5.58 In summary, the IBM can be described as follows: 'virtual' or surrogate fish are introduced into the existing physical model of the tidal Thames which incorporates the temporary and permanent Thames Tideway Tunnel project structures. In order to produce realistic fish behaviours within the model, the 'virtual fish' are ascribed rules which determine how they would react to changing physical cues such as channel edges, water depth tides and local hydraulic conditions. The model uses three species, dace, flounder and eel as agreed with the EA, as proxies for the various morphologies of fish represented in the tidal Thames. The behaviours ascribed to the model fish are based on a set of 'rules' derived from a combination of background literature review and field and laboratory studies (see Vol 3 Appendix C.2 for further details).

5.5.59 The model was set up to simulate the migration of a shoal of fish through the tidal Thames under the three development scenarios (i.e. base case scenario – no Thames Tideway Tunnel project structures; temporary/construction case – with temporary Thames Tideway Tunnel project structures; permanent development case – with permanent Thames Tideway Tunnel project structures). The model was run for five days for each of the scenarios. Each model run was seeded with the same number of fish (2500), and was based on the same geographic start and end points (1.5km west of the Thames Barrier at the downstream end to between Putney Bridge and Kew Bridge at the upstream end). Extensive testing of the model was undertaken to ensure that it was realistic in terms of its sensitivity to the various input parameters, such as fish swimming speed. Further details are presented in Vol 3 Appendix C.2.

5.5.60 The project-wide effects on juvenile fish migration could be expected to manifest themselves in two particular ways that can be estimated from the IBM. Firstly, more challenging hydraulic conditions could delay the progress of smaller, weakly swimming life stages through the tidal Thames, such that they do not become optimally distributed across all the available habitat; and secondly, the fish might fail to reach a target habitat by an critical date/time. This can be measured in the model by estimating the mean time to cross a notional finishing line (e.g. head of tide).

5.5.61 The model considers effects for the three species under three cases, i.e.

a. Baseline, (i.e.no development);

b. Temporary works

c. Permanent works

Assessment of effects

5.5.62 The following section considers the outputs of the model in the context of the assessment criteria described in Vol 2 Section 5. The potential impacts of delayed migration and increased mortality are assessed against an objective scale ranging from high negative (hydraulic conditions which may prevent fish from reaching life stage critical habitat) to negligible (chance of any impact is very low and if it occurs it is well below the level of detection). When combined with the value of the receptor (high (regional)) value any impacts of greater than low negative magnitude are likely to give rise to moderate, and therefore significant, effects.

5.5.63 The study found that there were small, statistically significant differences in the rate of upriver migration between the baseline and the temporary works scenarios. For example, for flounder there was a 3.3% difference in the mean (average) time taken for the population to undertake an upstream migration upstream between the baseline and temporary case. However, in real terms this represents a delay of a single tidal cycle, over a 5 day period, and is considered to arise as a result of the large size of the population sampled (2500 individuals) and therefore the inherent variation between individuals. Effects are thus considered to be negligible for flounder.

5.5.64 The effects of the temporary works on bass are advantageous, with the mean distance migrated over a 6 day period 4.4% greater than for the baseline case. This is likely to be due to the hydraulic conditions created around the structures giving rise to extra shelter from the tidal currents. However, the advantage is considered to be only slight and therefore overall effects on bass are negligible.

5.5.65 No difference between the temporary and baseline situations were predicted for eel and therefore effects are also negligible.

5.5.66 In terms of differences in mortality rate as a result of fish being forced into deeper water as they pass the structures, modelled mortality rates for the temporary and permanent works treatments vary little from the baseline case and statistical analysis confirms that any small differences seen are non-significant. The explanation for this is that, while structures may have the effect of forcing some fish into deeper water as they pass the structure, their instinctive and continuous searching for preferred lower velocity conditions rapidly brings them back into shallow water as and when it becomes available. Thus they would only spend a small proportion of their time in deeper water and even where the mortality risk is increased several fold, the exposure time is too small to make any significant difference.

5.5.67 Effects are thus also considered to be negligible for all three species.

5.5.68 Overall, given the high (regional) value of the receptor and the negligible impact level effects on fish as a result of changes flow velocity associated with the temporary structures are **negligible**.

Effects of waterborne noise and vibration on fish

5.5.69 In addition to the potential for physical injury arising from noise and vibration, fish may also exhibit behavioural responses to noise in the form of avoidance; this can have significant impacts on migratory species. Research was conducted into the avoidance behaviour of fish to differing computer-generated sounds at 12 sound levels (Nedwell et al, 2007)[76]. Experiments were conducted in a choice chamber with sound being played from alternating sides; any avoidance behaviour was recorded. Some fish, such as flounder, were found to be unsuitable subjects for reaction experiments as their natural behavioural avoidance response to is to hide by remaining in one position. This consequently did not register as an avoidance response in the experiment, as it was not physical movement away from the sound.

5.5.70 The Atlantic salmon is neither the most or least sensitive fish species to noise but is probably the species of highest conservation value that is encountered in the tidal Thames; additionally, as a migratory species its life cycle can be affected by 'acoustic barriers' across a river that may prevent that migration. According to information reported in the Estuarine Ecology chapter of the *Environmental Statement* for the Forth Bridge Replacement Crossing, salmon would be expected to demonstrate a mild behavioural response to sound at around 170 dBre1µPa and a strong response at 185 dBre1µPa.

5.5.71 The study by Nedwell and Edwards (2002)[77] reported that vibro-piling in the River Arun associated with construction of a quay wall produced underwater sound pressure levels of 132-152 dBre1µPa at distances of between 16m and 82m from the source.

5.5.72 Vol 3 Table 5.5.3 indicates that shipping movement that may be associated with the Thames Tideway Tunnel project construction (i.e. a tug pulling a loaded barge and a tug pulling an empty barge) sound pressure levels even at source fall below the levels identified as causing anything above a mild reaction in Atlantic salmon.

5.5.73 For the purposes of ecological assessment noise data is presented in terms of the dBht (Species) metric. This indicates the loudness of the noise that would be perceived by individuals of the given species. In general, sounds above 50 dBht (species) is used as a very precautionary indicator of disturbance in that this is the threshold above which a reaction to the sound by a majority of individuals would be discernable. A strong avoidance reaction by virtually all individuals is unlikely to occur until approximately 90 dBht (species) is reached[78].

5.5.74 During sound monitoring associated with works in Southampton Water work[79], analysis was undertaken to look at the possible impact on fisheries using the "dBht" metric. The dBht levels calculated indicated that the sound produced during impact piling was not greatly above the hearing threshold of salmon and trout within a few hundred metres of the operations, indicating that within Southampton Water the piling operations would have had no more than a small impact on the salmonids. The data indicated that sound levels dropped to below 50 dBht for both salmon and trout at distances of 200-300m.

5.5.75 Nedwell et al (2005) reported measurements of hydraulic piling operations as part of a flood alleviation scheme in the Malling Brooke cell of the River Ouse. The measurements were carried out in the centre of the river approximately 31m from the construction works with the hydraulic piling operation located approximately 20m from the river bank. From the data presented in the report it was found that hydraulic piling operations in this case caused very marginal increases in underwater noise above background noise levels in the river. Hydraulic piling or other low impact piling (e.g. vibro-piling) are therefore likely to cause an avoidance reaction only within a very localised zone around the activity.

5.5.76 Based on the importance of the receptor (high (Regional)) and the magnitude of the impact (low negative), the effect may be expected to be moderate adverse (Vol 2 Section 5.5). However, given that the species which occur within tidal Thames are likely to have a similar sensitivity to Atlantic salmon (para. 5.5.70) and based on the piling techniques proposed the effect is considered to be **minor adverse**.

5.5.77 It has already been identified that the effects of barge movements (particularly against a background of extensive barge movements within the tidal Thames) would result in noise and vibration levels that are unlikely to exceed the thresholds for disturbance except within the immediate vicinity of the barge. However, given the extent of the barging operation across all of the Thames Tideway Tunnel project sites this effect would also be **minor adverse**.

Water quality effects on fish and reduction in water column visibility due to suspended sediment

5.5.78 The predicted increases in suspended sediment due to general construction activity such as barging are not expected to affect fish populations given the existing background levels within the tidal Thames. However, high levels of suspended sediment which may occur as a result of sudden scour events could give rise to localised reductions in DO and potentially, increases in the concentrations of contaminants. Fish are likely to move away from these unfavourable conditions, but there is a risk of effects on fish health or even fish mortality.

5.5.79 Given the localised nature of any event, the ability of fish to move away from the source of the impact effects are considered to be **negligible**.

Invertebrates

Direct mortality of invertebrates due to temporary landtake, sediment disturbance and consolidation

5.5.80 There would be direct mortality of invertebrates within sediments affected by temporary landtake (3.5ha across the intertidal and subtidal zones), and due to consolidation and disturbance of sediment during the site establishment phase. The effect is considered to be **minor adverse** due to the low negative impact on the medium-high (metropolitan) value of the receptor.

Loss of burrowing and feeding habitat for invertebrates due to temporary landtake

5.5.81 The area beneath the temporary cofferdams would also be lost as burrowing and feeding habitat for invertebrates during the construction period. Given the medium-high (Metropolitan) value of the receptor and the low negative impact of habitat loss, the overall effect considered to be **minor adverse**.

Loss of feeding and burrowing habitat for invertebrates due to sediment disturbance and consolidation

5.5.82 Overall, there would be a maximum total loss of 12.5ha due to sediment disturbance and consolidation due to the activity of jack up barges during the site establishment stage. This habitat would be lost as burrowing and feeding habitat for invertebrates. This comprises 0.005% of the available habitat within the Thames Upper and Middle zones.

5.5.83 Based on the importance of the receptor (medium-high (Metropolitan)) and the magnitude of the impact (low negative), the effect may be expected to be minor adverse (Vol 2 Section 5.5). However, given the extent of alternative habitat, the overall effect is considered to be **negligible**.

Loss of feeding and burrowing habitat for invertebrates due to scour and accretion

5.5.84 The loss of silt and sand from intertidal habitats as a result of scour may reduce their suitability as feeding and burrowing habitat for invertebrates. Accretion of fine material could affect any filter feeding invertebrate such as mussels. However, filter feeding organisms form a relatively minor component of the benthic invertebrate community,

5.5.85 Subtidal habitats are already heavily scoured and contraction scour as a result of the temporary works is unlikely to change its suitability as invertebrate habitat.

5.5.86 Based on the importance of the receptor (medium-high (Metropolitan)) and the magnitude of the impact (low negative), the effect may be expected to be minor adverse (Vol 2 Section 5.5). However, given the extent of alternative habitat, the overall effect is considered to be **negligible**.

Blanketing of feeding areas for invertebrates and reduction in water column visibility due to accretion

5.5.87 As for fish, the predicted increases in suspended sediment due to general construction activity such as barging are not expected to affect invertebrate communities given the existing background levels within the tidal Thames. However, high levels of suspended sediment which may occur as a result of sudden scour events could give rise to localised reductions in dissolved oxygen and potentially, increases in the concentrations of contaminants.

5.5.88 The majority of the invertebrates recorded during bespoke Thames Tideway Tunnel project surveys and EA sampling are not considered to be particularly sensitive to sediment accretion or low dissolved oxygen conditions. These organisms are adapted to withstand tidal flows that bring about movements of degradable and non degradable solids. The feeding mechanisms of animals that filter water might be affected (e.g. larger bivalves), but these are sparsely recorded in the tidal Thames. Tube living animals such as Corophiidae might be more susceptible, but they are quite mobile and able to move away from sources of impact.

5.5.89 Given the negligible level of impact effects are thus considered to be **negligible**.

Increase in abundance/distribution of invasive species.

5.5.90 Disturbance to sediments and increased boat movements has the potential to cause spread and increased abundance of invasive species such as Chinese mitten crab and Asiatic clam. Given that these species are already widespread throughout the Upper and Middle Tideway zones, effects are considered to be **negligible**.

Algae

Loss of algal communities due to temporary landtake

5.5.91 Algal communities would be lost from the stretches of river wall immediately abutting and adjacent to the temporary and permanent cofferdams. In general the algal communities recorded at the Thames Tideway Tunnel project sites are characterised by widespread green algae species which are known to readily colonise new surfaces.

5.5.92 The presence of two marine red algal species (*R purpureum* and *P stricta*) at Chambers Wharf is notable since this is the most upstream record of these species. However, these species are widespread in the marine zone of the river and receive no legal protection.

5.5.93 The effects of temporary landtake on algal communities are considered to be **negligible**.

Restricted algal growth due to suspended sediment

5.5.94 Increases in water column turbidity may reduce light levels and thus inhibit photosynthesis in algal communities, particularly those near the foot of river wall which are infrequently exposed by the tide. The predicted increases in suspended sediment due to general construction activity such as barging are not expected to add significantly to the existing sediment loading of the river. Algal species which occur on the lower zone of the river wall are adapted to lower light conditions and are therefore likely to be insensitive to minor increases in suspended solids.

5.5.95 The effect is thus considered to be **negligible**.

Sensitivity test for programme delay

5.5.96 For the assessment of effects on aquatic ecology during construction, a delay to the Thames Tideway Tunnel project of approximately one year would not be likely to materially change the assessment findings reported above (Section 5.5). This is because there are no developments in the development schedule (see Vol 3 Appendix A.1) that would fall into the base case as a result of this delay and therefore the base case would remain as described in paras. 5.4.151 to 5.4.154.

5.6 Operational effects assessment

Operational impacts

Increases in dissolved oxygen concentrations in the tidal Thames

5.6.1 The Thames Tideway Tunnel project would result in a large reduction in volume, frequency and duration of combined sewage discharges to the tidal Thames. This would improve DO levels in the tidal Thames in general and would reduce the frequency of the episodic DO sags that result from the release of large volumes of untreated sewage over a short space of time.

5.6.2 Catchment modelling results show that in a typical year the main tunnel would reduce the total volume of untreated sewage entering the river by 15,360,000 m^3 to 2,363,000 m^3 (or 87% reduction) when compared to the operational base case.

5.6.3 Compliance with the DO standards for the tidal Thames has been modelled for the following scenarios and the results presented in Vol 3 Table 5.6.1:

a. existing system,

b. the Lee Tunnel and sewage treatment works upgrades (i.e. the operational base case) and

c. the operational base case plus the Thames Tideway Tunnel project.

5.6.4 For all scenarios tested, the biggest summer rainfall events (over 100 in total) over a period of 41 years were modelled and each scenario subsequently tested for compliance against the DO thresholds to determine whether they had been exceeded and for how long. When all 41 years of data are considered, the return periods for each DO threshold give rise to an ‘allowable’ number of times when the threshold can be exceeded. Further details of the modelling used to underpin the standards are presented in Vol 2 Section 14.8.

Vol 3 Table 5.6.1 Aquatic ecology – DO standard compliance

DO Standard	**1**	**2**	**3**	**4**
DO value and tidal duration threshold	**4 mg/l for 29 tides***	**3 mg/l for 3 tides**	**2 mg/l for 1 tide**	**1.5 mg/l for 1 tide**
Allowable exceedances in 41 years (frequency)	**41 (1:1yr)**	**13 (1:3yr)**	**8 (1:5yr)**	**4 (1:10yr)**
Scenario	Simulated maximum number of exceedances of DO thresholds			
Existing System	211	193	99	60
	Fails**	Fails	Fails	Fails
STWs Improvement and Lee Tunnel	75	40	12	7
	Fails	Fails	Fails	Fails
STWs Improvements, Lee Tunnel and Thames Tideway Tunnel (Recommended Plan)	21	4	1	1
	Compliant***	Compliant	Compliant	Compliant

** A tide is a single ebb or flood.*

*** Failure occurs when the predicted number of exceedances is greater than the allowable number of exceedances over the number of years of CTP events simulated*
****Although there are exceedances of the standard (that is the DO is less than the standard value for the number of tides in the standard) the number of exceedances over the 41 year is less than the allowable number (the frequency of occurrence criteria) is met so the result is compliant.*

5.6.5 Details of the modelling study are presented in Vol 3 Section 14. The results show that only when the Thames Tideway Tunnel project is included in modelled scenarios is it possible to achieve all DO standards throughout the tidal Thames. The results show that with the Thames Tideway Tunnel project in place, the tidal Thames would pass DO standards at all locations with several additional breaches of each standard still being permissible before the standard was failed.

5.6.6 The Thames Tideway Tunnel project represents one in a suite of measures known as the Thames Tideway Quality Improvements which also includes the Lee Tunnel and sewage treatment works upgrades (at Mogden, Beckton, Crossness, Long Reach and Riverside), aimed at improving water quality and achieving sustainable levels of dissolved oxygen for tidal Thames fish populations and other wildlife. The reduction in the number of failures of the DO standards achieved by these schemes is shown in Vol 3 Table 5.6.1.

5.6.7 Since the Lee Tunnel and sewage treatment works upgrades will be operational prior to the completion of construction of the Thames Tideway Tunnel project their contribution to the improvements in the sustainability of fish, invertebrate and algae population are described in the base case (para. 5.4.151).

5.6.8 The benefits to fish and other wildlife which will accrue from the suite of TTQI schemes represent a high positive impact. Based on the definition in Vol 2 Section 5.5 this can be defined as a ‘substantial change of ecosystem functioning, with gain of species and gain of diversity, notably rarer more sensitive species’. However, given that part of this substantial change has already been achieved through the Lee Tunnel and sewage treatment works upgrades the incremental improvement achieved by the Thames Tideway Tunnel project represents a medium positive impact. It is defined by the fact that compared with the base case the abundance of some of the more sensitive species would increase more widely, and the changes would be longer lasting and less prone to detrimental impacts.

5.6.9 Predicted effects on the individual aquatic ecology receptors are described in para. 5.6.23 to 5.6.77. Impacts would be certain and permanent.

Reduction in sediment nutrient levels

5.6.10 Elevated concentrations of nutrients (phosphate and nitrate) are likely to have accumulated in the sediments in proximity to the discharge point as a result of suspended solids or sediment discharged from the CSOs. Increased nutrients in the sediment can reduce the natural limits on algal growth and enable more nitrogen/phosphate responsive species to outcompete other species reducing diversity. Interception of the CSOs would give rise to an overall reduction in the discharge of suspended solids and total organic nitrogen (TON) to the tidal Thames of 2,200,000t or 12.4%. Over time this reduction in the discharge of suspended solids is likely to lead to a gradual reduction in sediment nutrient levels. The impact is considered to be low positive, probable and permanent.

Reduced levels of sewage derived litter

5.6.11 There would be an approximate reduction of 3,888 tonnes in sewage derived litter entering the tidal Thames annually leaving a residual 580t in a typical year. The impact is considered to be low positive, probable and permanent.

Permanent landtake due to the presence of permanent structures on the foreshore

5.6.12 There would be 0.74ha of landtake from intertidal, and 0.59ha from subtidal habitats associated with the permanent foreshore structures (Vol 3 Table 5.6.2). There would be 824m^2 of intertidal habitat created at Albert Embankment and Dormay Street. The permanent loss represents 0.1% of the total area of the River Thames and Tidal Tributaries SINC (Grade M), and 0.2% of its intertidal and 0.04% of its subtidal habitats respectively. Impacts associated with landtake are considered to medium negative, since although it is a small percentage of the tidal Thames it represents a permanent loss of habitat.

Vol 3 Table 5.6.2 Aquatic ecology – permanent change in habitat area from sites on the Thames foreshore

Thames Tideway Tunnel project site	Area of permanent gain of intertidal habitats (m^2)	Area of permanent landtake (m^2) from intertidal habitat	Area of permanent landtake (m^2) from subtidal habitat	Area of permanent spill apron and scour protection (m^2) on intertidal habitat	Area of permanent spill apron and scour protection (m^2) on subtidal habitat	Area as percentage of SINC (Upper or Middle Tideway zone in brackets)
Putney Embankment Foreshore		600	0	700	500	0.008 (Upper = 0.03)
Carnwath Road Riverside		0	0	0	0	0
Dormay Street	104					
Chelsea Embankment Foreshore		1200	0	2000	400	0.02 (Middle = 0.02)
Kirtling Street		0	0	0	0	0
Heathwall Pumping Station		600	0	700	50	0.006 (Middle = 0.008)
Albert Embankment Foreshore	720	2500	0	1100	500	0.02 (Middle = 0.02)
Victoria Embankment Foreshore		0	1100	0	0	0.005 (Middle = 0.006)
Blackfriars Bridge Foreshore		800	4400	350	1300	0.03 (Middle = 0.04)
Chambers Wharf		0	0	0	0	0
King Edward Memorial Park		1700	400	300	1300	0.02 (Middle = 0.02)

Thames Tideway Tunnel project site	Area of permanent gain of intertidal habitats (m^2)	Area of permanent landtake (m^2) from intertidal habitat	Area of permanent landtake (m^2) from subtidal habitat	Area of permanent spill apron and scour protection (m^2) on intertidal habitat	Area of permanent spill apron and scour protection (m^2) on subtidal habitat	Area as percentage of SINC (Upper or Middle Tideway zone in brackets)
Foreshore						
TOTAL	824	7400	5900	5150	4050	0.1

Modification of habitat as a result of scour protection measures

5.6.13 The outfalls at each of the permanent Thames Tideway Tunnel project sites would include an apron to prevent residual discharges scouring the surrounding bed. Scour protection is also required around the perimeter of the permanent structures. Scour protection (including aprons) would comprise buried rip rap. A total area of 0.9ha across all of the Thames Tideway Tunnel project sites would be affected by scour protection.

5.6.14 The scour protection is considered to be a low negative impact, certain and permanent.

Change to scour and accretion patterns

5.6.15 Scour protection measures are proposed to offset permanent abutment scour effects at each of the CSO outfalls and foreshore structures (para. 5.6.13). Contraction scour (para. 5.5.10) is predicted for permanent structures. However, as the permanent structures would be smaller than the temporary works, the resultant scour would also be less.

5.6.16 With the permanent structures in place, some sediment accumulation is predicted to occur in the intertidal and subtidal zones immediately upstream of the permanent foreshore structures. These predicted areas of sediment and accumulation are illustrated in Section 14 of this volume.

5.6.17 Impacts due to scour and accretion are considered to be **negligible,** probable and permanent.

Changes to the hydraulic regime

5.6.18 In addition to scour changes in flow velocities in the vicinity of the permanent works may affect the ability of smaller, weakly swimming fish (mainly juveniles) to remain in habitat within the hydraulic footprint of the construction area or to move past the structure.

5.6.19 The modelling studies indicate that flow velocities would increase particularly around the outer corners of the permanent structures. However, lower velocities would also occur in the lee of the structures thus providing refuges for pelagic species of fish and invertebrates

5.6.20 Overall, the impact of the change to the hydraulic regime as a result of the permanent structures is considered to be negligible, probable and permanent.

Operational effects

5.6.21 The operational receptors and their value are identical to that of the construction receptors and are thus not reproduced here. The effects are described below for each receptor. The way in which the magnitude and reversibility of each impact has been combined with the value of each receptor to determine the significance of the effect is set out in Vol 2 Section 2.

5.6.22 Unless stated the effects described below apply to both Year 1 of operation and Year 6 of operation.

Designations and habitats

Improvements in DO concentrations

5.6.23 The assessment of effects on the Thames Estuary and Marshes SPA is presented in the report to inform a *Habitats Regulations Assessment: No Significant Effects Report* which accompanies the application. The report concluded that there would be no Likely Significant Effects of the Thames Tideway Tunnel project on any European sites, either alone or in-combination with other projects and plans. Effects on this designated site are thus considered to be **negligible**.

5.6.24 The Inner Thames Marshes SSSI consists primarily of grazing marsh habitat. Although the habitat is hydrologically connected to the Thames estuary, the changes in water quality predicted as a result of the Thames Tideway Tunnel project are not considered to result in any changes in water quality within the ditch network which supplies the marshes. Water quality fluctuations within this habitat are likely to be dependent on nearby point sources of pollution and land management practices, such as fertiliser run off from pasture.

5.6.25 Based on the importance of these sites (high (International) for the Thames Estuary and Marshes SPA and high (National) for the Inner Thames Marshes SSSI) the low positive impacts would give rise to a moderate beneficial effect. However, given the distance of the sites from the CSO discharges, and the sensitivity of the habitats to the water quality improvements which would occur, the effect is considered to be **negligible**.

5.6.26 For habitats within the River Thames and Tidal Tributaries SINC (Grade M) reduction in CSO discharges may be expected to lead to an immediate increase in DO concentrations within surface substrates, particularly those in the immediate vicinity of discharges. Given their medium-high (metropolitan) importance and the medium positive impacts of DO improvements, effects are considered to be **moderate beneficial**.

5.6.27 Of the remaining non-statutory sites scoped into the assessment (Vol 3 Table 5.4.1), Lavender Pond LNR and Leg of Mutton Reservoir LNR are not hydrologically connected to tidal Thames and therefore would not be affected. The Isleworth and Chiswick Ayots include both terrestrial and intertidal habitats. They are expected to undergo **minor beneficial** effects from the increase in DO.

Reduction in sediment nutrient levels and sewage derived litter

5.6.28 No effects from the reduction in sediment nutrient levels and sewage derived litter are anticipated for the Thames Estuary and Marshes SPA and the Inner Thames Marshes SSSI.

5.6.29 The 12.4% reduction in discharges of suspended solids and total organic nitrogen would lead to improvements in habitat quality, particularly for those gravel substrates in the Upper Tideway which provide important feeding and spawning habitat for fish. Deposition of sediments, particularly organic solids arising from sewage can degrade gravel habitats, and lead to a reduction in DO concentrations in the gaps or interstices between gravel particles. Sediment nutrient levels are anticipated to reduce over time allowing habitats to return to more natural conditions. Furthermore, the reduction in the occurrence of sewage litter would have benefits to habitats. Significant quantities of plastic waste are currently deposited on the foreshore, and degrade into small fragments which are taken up by organisms and enter the food chain. The Acton Storm Tanks CSO currently discharges into the tidal Thames at Chiswick Ayot. The reduction in discharges at this site is likely to lead to an improvement in habitat quality of the Ayot, due to a reduction in sewage derived litter, and reductions in sediment nutrient levels. The Ayot provides important nursery habitat for fish and is known to support the rare two lipped door snail. Given their medium-high (metropolitan) importance, and the low positive impacts of reduced sewage litter and reduction in sediment nutrient levels effects on habitats within the Chiswick and Isleworth Ayots and the River Thames and Tidal Tributaries SINC (Grade M) are considered to be **minor beneficial**.

5.6.30 No effects on the remaining non-statutory sites are anticipated.

Permanent loss of intertidal and subtidal habitats

5.6.31 There would be no landtake from the Thames Estuary and Marshes SPA or the Inner Thames Marshes SSSI. There would be no permanent landtake from the non-statutorily designated sites, with the exception of the River Thames and Tidal Tributaries SINC (Grade M). Effects on this site are assessed in para.5.6.32.

5.6.32 The permanent landtake involved in the construction of the Thames Tideway Tunnel project would amount to 13,300m^2 which is 0.1% of the River Thames and Tidal Tributaries SINC (Grade M) (0.008% of the Thames Upper and 0.1% of the Thames Middle). The habitats affected by permanent landtake are presented in Vol 3 Table 5.6.2 and include gravel foreshore, intertidal mudflat and subtidal gravels. These habitats are well represented across the Thames Upper and Thames Middle zones, and the total loss as a proportion of the total area of intertidal and subtidal habitat is small. These losses are not considered to affect the integrity (i.e. the coherence of ecological structure and function) of intertidal and subtidal habitats.

5.6.33 Nevertheless, it is recognised that development on the foreshore is contrary to the Environment Agency's encroachment policy6 It may also affect the delivery of measures identified in the Thames *River Basin Management Plan*[80] which will ensure the tidal Thames achieves Good Ecological Potential under the Water Framework Directive. Specifically, the mitigation measure to 'preserve and where possible enhance ecological value of marginal aquatic habitat, banks and riparian zone'. An assessment of the project against objectives under the Water Framework Directive is presented in Vol 3 Appendix L.2.

5.6.34 On this basis, given the importance of the River Thames and Tidal Tributaries SINC (Grade M) (medium-high (metropolitan) and the medium negative impact the overall effect is considered to be **moderate adverse.**

Modification of intertidal and subtidal habitats

5.6.35 The installation of buried rip rap as scour protection would lead to some permanent change in habitat structure in those affected areas. Changes would be most pronounced in those areas such as Victoria Embankment Foreshore where the intertidal zone is currently characterised by finer material such as sand, silt and fine gravels.

5.6.36 Although there may be some scour of material overlying the rip rap it is expected to support habitat which can be colonised by benthic invertebrates. Effects are considered to be **minor adverse** given the low negative magnitude of the impact and the medium-high (metropolitan) value of the receptor.

Marine mammals

Increase in the number and/or change in the distribution of marine mammals

5.6.37 No detectable changes are anticipated on marine mammals as a result of the water quality improvements associated with interception of CSO discharges throughout the tidal Thames. This is because they are a mobile receptor, and therefore able to move away from point sources of discharge. However, ingestion of litter and particularly plastic wastes can result in injury or mortality of marine mammals. The reduction in sewage derived litter entering the tidal Thames is likely to reduce the risk of these events occurring.

5.6.38 Given the high (regional) value of the receptor, effects are considered **negligible** at Year 1 and **minor beneficial** at Year 6 of operation.

Fish

Reduction in the occurrence of dissolved oxygen related fish mortalities

5.6.39 Outputs from the TFRM demonstrate that during operation any mortalities associated with hypoxia would reduce, achieving sustainable populations of fish (i.e. would not result in the loss of more than 10% of the population) across all the indicator species and life stages. Since the model is based on DO requirements of the most sensitive species the ecology of the tidal Thames as a whole should be protected from damage associated with hypoxia.

5.6.40 Vol 3 Table 5.6.3 shows the predicted levels of mortality for each of the seven indicator species against the DO standards. The DO standards are described in para. 5.4.58. Mortalities for all species fall below the 10% criterion by a large margin (generally <1% mortality), indicating a safety margin for future deterioration e.g. with climate change or commercial fishing activity. The DO standards are presented in Vol 3 Table 5.6.1.

5.6.41 Para. 5.6.7 describes the relationship between Thames Tideway Tunnel project and the Lee Tunnel and sewage treatment works upgrades and their contribution to achieving high positive impacts on fish and other aquatic ecology receptors. Taken together these schemes would have a major beneficial effect on tidal Thames fish populations.

5.6.42 The impact of the Thames Tideway Tunnel project against the base case is considered to be medium positive since it represents the incremental improvement in DO required in order to achieve sustainability for all fish populations within the tidal Thames.

5.6.43 The impact of the DO improvements on surface water bodies is assessed as major beneficial (Vol 3 Section 14.6) compared with a moderate beneficial effect for aquatic ecology receptors. This is because the assessment methodology for surface water (Vol 2 Section 14.5) defines a major beneficial effect as one 'which would allow the requirements of the UWWTD or other legislative targets to be met'. The aquatic ecology methodology defines a high positive impact as 'substantial change of ecosystem functioning, with gain of species and gain of diversity, notably rarer more sensitive species' (Vol 2 Section 5.5). Thus whilst the two assessments are related, their subject matter is different.

5.6.44 Taken together with the Lee Tunnel and sewage treatment works upgrades the impact of the improvements in DO arising from the Thames Tideway Tunnel project are considered to be a high positive impact on aquatic ecology receptors.

5.6.45 However, given that part of this substantial change has already been achieved through the Lee Tunnel and sewage treatment works upgrades the incremental improvement achieved by the Thames Tideway Tunnel project represents a medium positive impact.

5.6.46 Given the high (regional) importance of the receptor the effects are considered to be **moderate beneficial**.

Vol 3 Table 5.6.3 Aquatic ecology – population level annual mortality rates associated with hypoxia for the indicator species from the TFRM model with the Thames Tideway Tunnel project

Species	Life stage	Standard 4	Standard 3	Standard 2	Standard 1
		Population Level Effect			
Salmon	Smolt	0.00%	0.00%	0.08%	0.15%
	Adult	0.71%	1.05%	5.52%	2.70%
Bass	Young Fry	0.00%	0.00%	0.00%	0.22%
	Juvenile	0.07%	0.11%	0.61%	2.70%
Sand smelt	Egg/fry	0.00%	0.00%	0.00%	0.00%
	Juvenile	0.07%	0.11%	0.61%	2.79%
	Adult	0.07%	0.11%	0.61%	4.34%
Dace	Egg/fry	0.00%	0.00%	0.00%	0.17%
	Juvenile	0.57%	0.17%	0.26%	0.47%
	Adult	0.19%	0.17%	0.26%	0.47%

Species	Life stage	Standard 4	Standard 3	Standard 2	Standard 1
		Population Level Effect			
Smelt	Egg/fry	0.00%	0.00%	0.00%	0.00%
	Juvenile	0.07%	0.11%	0.65%	2.79%
	Adult	0.00%	0.05%	0.83%	4.34%
Flounder	Egg/fry	0.00%	0.00%	0.00%	0.00%
	Juvenile	0.07%	0.16%	0.61%	2.70%
	Adult	0.00%	0.10%	0.82%	4.03%
Common goby	Egg/fry	0.00%	0.00%	0.00%	0.00%
	Juvenile	0.07%	0.11%	0.61%	2.70%
	Adult	0.00%	0.00%	0.00%	0.00%
	Average	0.10%	0.12%	0.60%	1.61%

Increase in the distribution of pollution sensitive fish species

5.6.47 For the purposes of this assessment pollution sensitive species may be considered to be those which have a high sensitivity to hypoxia. Of the species which occur in the tidal Thames Atlantic, salmon and smelt have the highest sensitivity, followed by dace. Certain rare species such as allis shad may also be restricted by hypoxia.

5.6.48 The effects on Atlantic salmon and smelt were modelled using the TFRM. Vol 3 Table 5.6.3 shows that with the Thames Tideway Tunnel project the percentage of population which would suffer mortality as a result of hypoxia is reduced to below the 10% threshold which is considered necessary to sustain the population in the long term.

5.6.49 Rare species such as Allis Shad were not included within the TFRM since there is insufficient population data and their distribution is likely to be limited by factors other than hypoxia such as habitat availability.

5.6.50 Based on the importance of the receptor (high (regional)) and the magnitude of the impact (medium positive), the effect may be expected to be moderate positive (Vol 2 Section 5.5). However, given that the distribution of pollution sensitive species such as Atlantic salmon and Allis shad is currently influenced by a range of factors, including habitat availability and spawning success, the effects of improved water quality on their distribution is considered to be **minor beneficial**.

Permanent loss of intertidal spawning, feeding and resting habitat for fish due to landtake

5.6.51 There would be no encroachment of permanent structures into the subtidal zone at Putney Embankment Foreshore, which lies immediately upstream of the reach where smelt are known to spawn and within the zone where dace spawn . There is no permanent landtake at Carnwath Road

Riverside which lies within smelt spawning zone. The effects of landtake on spawning habitat are therefore considered to be negligible.

5.6.52 In most cases the permanent foreshore structures lie primarily within the shallow intertidal zone of the river, which offers feeding and migratory habitat for juvenile fish. Permanent landtake represents 0.15% of the area of intertidal and subtidal habitats in the Middle and Upper Tideway. The intertidal habitats affected by landtake are well represented throughout the Upper and Middle Tideway therefore this is not considered likely to affect the integrity of the feeding resource for fish. Effects on juvenile fish migration are dealt with in paras. 5.6.58 to 5.6.63.

5.6.53 Given the importance of the receptor (high (regional)) and medium negative magnitude of impact, effects are considered to be **moderate adverse**.

Modification of intertidal feeding and subtidal habitat for fish

5.6.54 At Putney Embankment Foreshore, scour protection would occupy an area 1200m^2 including 700m^2 within subtidal habitat which may represent spawning habitat for smelt since it lies immediately upstream of the zone which is known to spawning habitat. Whilst the buried rip rap offers some benefits for fish by improving the heterogeneity of otherwise uniform habitats, it is unlikely to have value as spawning habitat since smelt are known to select gravel habitats. However, since the area affected is small, and lies outside the core spawning area it is not considered likely to affect the availability of spawning habitat for smelt in the Upper Tideway.

5.6.55 The rip rap areas may offer some benefits to juvenile fish by providing refuges from the current and from predators, particularly given its location within the shallow intertidal areas. In this respect it is analogous to artificial reef structures created in the marine environment to provide shelter for fish and increase the heterogeneity of otherwise uniform habitats.

5.6.56 Similarly, the rip rap may offer shelter for pelagic invertebrates such as *Gammarus* which represent a food source for some fish species. It is unlikely to have potential as feeding habitat for benthic feeding fish except where accretion allows colonisation by invertebrates.

5.6.57 Based on the matrix in Vol 2 Section 5.5 the effect of a low negative impact on a high (regional) receptor may be considered to be moderate adverse. However, given that there would be some benefits to fish the overall effect is considered to be **minor adverse**.

Interference with migratory movements of fish

5.6.58 The potential hydraulic effects of the permanent structures on fish migration were assessed using the IBM described in para. 5.5.58 and Vol 3 Appendix C.2. As for the temporary structures, the assessment has been considered in the context of whether the structures may delay juvenile fish migrations, or result in a higher mortality rate due to juvenile fish being forced into deeper water where predation rates are greater.

5.6.59 The modelling shows that there would be no significant differences in the rate at which fish migrate through the estuary between the baseline and the permanent case. The differences are greatest for flounder (rate of progress is 6.9% slower for the permanent works compared with the baseline). However, this is considered to be as a result of the large number of individuals within the modelled population.

5.6.60 For elver, the rate of progress is practically indistinguishable for the permanent case compared with the baseline. For bass, the permanent case is slightly more favourable than the base line, which is likely to reflect their use of the structures to shelter from the current. Interestingly, the rate of progress for the permanent case is slightly less favourable than the temporary case. This is considered to be because the more angular temporary structures are considered to offer more effective shelter than the streamlined permanent structures.

5.6.61 Similarly, there are only small differences in the mortality rate for any of the three species between the baseline and the permanent case. The differences between the works are only noticeable in the case of flounder and in the area immediately downstream of Blackfriars Bridge where the permanent works is higher than the base case. It is likely that this is related to a flood tide gyre that forms which can trap the fish (in relatively slow moving but deep water).

5.6.62 Overall, mortality risk is not significantly higher over the whole tidal Thames. This is because although fish are forced into deeper water by the structures, their instinctive search for lower velocity conditions brings them back into shallow water when it becomes available. Thus, although they spend time in deeper water where mortality rates due to predation are higher, this is such a small proportion of the time spent migrating through the channel that the losses due to mortality are insignificant. Overall, the effects on migration rates and mortality of the temporary structures on all three species are considered to be negligible.

5.6.63 Given the high (regional) value of the receptor and the negligible impact level effects on fish as a result of changes flow velocity associated with the permanent structures are **negligible**.

Invertebrates

River wide improvements in invertebrate diversity and abundance due to improved water quality

5.6.64 The natural changes in species composition that are expected with distance down an estuary are evident within the tidal Thames. However, the existing baseline data demonstrates that faunal diversity is much lower than expected in the middle region from Cadogan to Mucking due to the periodically very low DO and persistent DO sags especially during summer. In the localised areas around the CSO discharges there is a tendency for the less saline tolerant invertebrates to become more abundant in the locally fresher conditions. It is likely that both salinity and pollution restrict the distribution of a range of species that appear to be attempting (and failing) to colonise the middle region.

5.6.65 It has already been identified that invertebrate diversity and abundance may increase considerably under the base case due to the Lee Tunnel and sewage treatment works upgrades. However, even with these improvements in place there are still predicted to be a number of occasions during an average year when DO standards would be breached. Colonisation by DO sensitive taxa such as Corophiidae, Crangonidae and Gammaridae which would otherwise occur within the brackish zone would continue to be suppressed.

5.6.66 Full compliance with the standards is expected to enable colonisation by these DO tolerant taxa. In the localised areas around CSO discharges gradual reductions organic material associated with sewage would also allow for a transition from invertebrate communities dominated by small numbers of species to a more diverse and balanced community.

5.6.67 As with the assessment of water quality improvements on tidal Thames fish populations, taken together the Lee Tunnel and sewage treatment works upgrades the Thames Tideway Tunnel project would have a major positive impact on invertebrate populations. However, given that the incremental impact is considered to be medium positive and the value of the receptor is medium-high (Metropolitan) the effect is considered to be **moderate beneficial**.

Increase in the distribution of pollution sensitive invertebrate species due to improved water quality

5.6.68 A number of invertebrate taxa and groups considered to be sensitive to low dissolved oxygen conditions have been recorded in the tidal Thames. However, in most cases they occur only occasionally within the data set, and in low numbers. However, all groups are known to have short generation times and are therefore likely to be ‘opportunist’ animals, able to colonise quickly. Because water quality is not good for sufficiently long enough periods of time, other species that have longer generation times are generally not able to colonise.

5.6.69 A group that is largely absent and may be expected to be present in higher numbers is larger molluscs, notably large bivalves in the upper estuary. With the exception of *Corbicula fluminea* (Asiatic clam) and *Dreissena polymorpha* (zebra mussel), no larger molluscs were recorded. There are records of some Unionidae, a few individuals of the swan mussel *Andodonta complanata* (Attrill, 2008) but no other species. This may be partly because the sampling methods used in the upper estuary do not efficiently sample the types of deep water habitat favoured by these groups, so there numbers are underestimated. Many taxa are also likely to be limited by the variations in salinity. However, species such as *Unio pictorum* (painters mussel), *Unio tumidus* (swollen river mussel) and *Andodonta complanata* (swan mussel) can tolerate similar ranges in salinity as Dreissena (Verbrugge *et al*, 2011[81]), found in the tidal Thames as far downstream as Cremorne Wharf. These are often found in tidal rivers, including the upper reaches of the tidal River Arun (URS Scott Wilson, 2011[82]; Willing, 2005[83]; Willing, 2006[84]). Water quality is an important factor for *Pseudanodonta complanata* (depressed river mussel)[85]. Of all molluscs, large unionid bivalves are generally considered most sensitive to low DO (Mouthon, 1996[86]). The biological cycle of Unionidae begins with an obligatory parasitic stage of different species of fish. Thus their sensitivity and potential recovery in the Thames will be directly related to that of the host fish. The Unionids *Unio pictorum* and *Anodonta cygnea* have reappeared in the Rhine following significant improvements in DO concentrations (Bless, 1981[87]).

5.6.70 Other mollusca groups known to be among the most sensitive to pollution, were notably absent from the Thames samples. For example pollution sensitive groups such as *Anisus* spp., *Planorbis* spp., and *Bythinia* sp. include taxa that are tolerant to the types variations in salinity experienced in the upper estuary. These may start to be found within tidal Thames following improvements in water quality.

5.6.71 Based on the importance of the receptor (medium-high (Metropolitan)) and the magnitude of the impact (medium positive), the effect may be expected to be moderate positive (Vol 2 Section 5.5). However, given that the distribution of pollution sensitive species is likely to be influenced by a range of factors, including habitat availability, the effects of improved water quality on their distribution is considered to be **minor beneficial**.

Permanent loss of intertidal feeding and burrowing habitat for invertebrates due to landtake

5.6.72 The area beneath the permanent cofferdams would be lost as a feeding habitat for benthic invertebrates. However, these habitats are well represented throughout the tidal Thames, the species composition is relatively uniform and the invertebrate communities widespread throughout the study area. Based on the significance matrix (Vol 2 Section 5.3) effects would be considered to be moderate adverse. However, the significance is reduced to **minor adverse** due to availability of alternative habitat and the widespread nature of the invertebrate communities.

Modification of intertidal and subtidal habitats for invertebrates by scour protection

5.6.73 As for fish the degree to which the scour protection would change conditions for invertebrates depends on the nature of the existing substrate. Fine substrates are unlikely to accumulate extensively within the rip rap given that high flow velocities which are likely to occur in the vicinity of them. Benthic invertebrates may thus be excluded from these areas, except in sheltered pockets where accretion can occur.

5.6.74 Pelagic invertebrates such as *Gammarus zaddachi* may be attracted to these areas in order to shelter from the current.

5.6.75 Given the medium-high (metropolitan) value of the receptor and the low negative magnitude of the impact the overall effect on invertebrates is considered to be **minor adverse.**

Algae

Localised improvements in algal diversity and abundance

5.6.76 The diversity and abundance of algal communities in the tidal Thames is primarily influenced by salinity, shading and the availability of suitable substrates for colonisation. However, poor water quality, particularly during the 1950's and 1960's is identified as one of the causes for the loss of algal species from the tidal Thames.

5.6.77 It is possible that improvements in water quality in the upper and middle tidal Thames may benefit algal communities through increased abundance and distribution of pollution sensitive species. Given the medium (Borough) importance of the receptor and the medium positive magnitude of impact the effect is considered to be **minor positive**.

Sensitivity test for programme delay

5.6.78 For the assessment of effects on aquatic ecology during operation, a delay to the Thames Tideway Tunnel project of approximately one year would not be likely to materially change the assessment findings reported above (Section 5.5). This is because there are no developments in the development schedule (Vol 3 Appendix A.1) that would fall into the base case as a result of this delay and therefore the base case would remain as described in paras. 5.4.156 - 5.4.158.

5.7 Cumulative effects assessment

Construction effects

5.7.1 There are several schemes with the potential for cumulative effects during the construction stage. The Battersea Power Station scheme located 470m downstream of Chelsea Embankment Foreshore and 360m upstream of Kirtling Street. During construction of this scheme, there would be works on the jetty that would require both capital and maintenance dredging, and construction of a floating pontoon with steel mono piles. There is potential for impacts on aquatic ecology receptors through increased waterborne noise and vibration, and increased sediment loads.

5.7.2 If piling for the Battersea Power Station scheme coincided with piling operations for the Chelsea Embankment and Kirtling Street sites it is possible that the cumulative noise impact could disturb fish and prevent migration past the series of sites to feeding and spawning habitat in the upper tidal Thames. However, sound levels associated with vibro-piling fall to below 50dBht (the hearing threshold for salmon; para. 5.5.74) at distances of 200-300m from the source. On this basis, and assuming that vibro-piling is used at Battersea Power Station, there is no overlap in the zone of influence of piling noise between the three sites.

5.7.3 The only other scheme with potential for cumulative effects would be the Lots Road Power Station and Chelsea Creek development, which lies in close proximity to Cremorne Wharf Depot. During construction of the Lots Road Power Station schemes, there will be works to Chelsea Creek, including the construction of three pedestrian bridges. The Chelsea Creek scheme will include the formation of a water basin, two canals and navigable lock to replace existing Chelsea Creek barrier gates. However, the construction stage at Cremorne Wharf Depot has been concluded to lead to only negligible impacts on aquatic ecology receptors, and there is no mechanism whereby that effect would be elevated when considered cumulatively with Chelsea Creek and Lots Road. No cumulative effects from this development are therefore anticipated.

5.7.4 No other cumulative impacts at a wide scale are anticipated during the construction stage.

Operational effects

5.7.5 No cumulative impacts are anticipated during the operational stage.

Sensitivity test for programme delay

5.7.6 In the event that the programme for the Thames Tideway Tunnel project is delayed by approximately a year, the cumulative effects assessment would remain unchanged. As described above, there are no schemes anticipated to generate cumulative effects on aquatic ecology and this would remain the case with a programme delay of approximately one year.

5.8 Mitigation and compensation

5.8.1 The approach to mitigation has been informed by the ‘Mitigation and Compensation Hierarchy’ discussed with the Thames Tideway Tunnel Biodiversity Working Group as a systematic and transparent decision-making process. The hierarchy is sequential and seeks to avoid adverse environmental effects. The hierarchy of ‘avoid effect’, ‘minimise’, ‘control’ ‘compensate’, and ‘enhance has been strictly applied to the assessment process. The mitigation hierarchy is described in detail in Vol 2 Section 5.

5.8.2 The following section describes how the mitigation hierarchy has been applied across the Thames Tideway Tunnel project sites.

Avoid impact

5.8.3 There has been a reduction in the number of foreshore sites through the iterative design development process. For example, sites at Borthwick Wharf, Jews Row and Barn Elms were relocated on land following the phase one consultation process. Although new foreshore sites have been identified during the course of the design process, the number of sites where there would be permanent structures on the foreshore has decreased from eleven under the preferred scheme (i.e. prior to phase one consultation) to seven in the final project.

Reduce impact

5.8.4 Through a process of detailed design iteration, site layouts have been optimised and footprints minimised to reduce adverse impacts on aquatic ecology. For example, at Putney Embankment Foreshore, an early option (Phase 1) for the construction phase showed the temporary slipway on the outside of the temporary cofferdam. By moving the slipway further upstream and adjacent to the river wall, impacts on subtidal foreshore habitats have been reduced. A further design iteration has reduced the impact further by using a steel platform ramp for the temporary slipway instead of a cofferdam.

5.8.5 Where possible the size of the permanent structures have been reduced, for example, at both Blackfriars and King Edward Memorial Park. There has been a move from foreshore to inland sites, for example from Borthwick Wharf to Deptford Church Street. Further information on alternatives between sites is presented in Vol 1Section 3. Design development at each site is presented in Section 3.6 of each site assessment volume (Vols 4 to 27).

Control/abate impacts at source

5.8.6 Impacts during the construction stage would be controlled through the *CoCP*. Measures relevant to aquatic ecology are described in para. 5.2.18. They include the adoption of vibro piling techniques and the development of a *Lighting management plan* to minimise impacts on fish. A method statement has been developed for the reinstatement of foreshore sites to ensure that the temporary impacts on underlying habitats are minimised. The method statement is presented in Vol 3 Appendix C.4.

5.8.7 Where possible, measures have been incorporated into the design of the permanent structures to enhance their value for aquatic ecology receptors. These design principles are presented in paras. 5.2.25 to 5.2.27. They include the use of timber fenders on the riverward face of the permanent structure to provide refuges for fish and habitat for invertebrates and algae. A linear box feature with vertical fish egg laying strips at the foot of the permanent structures would provide an additional habitat feature to aid the passage of juvenile fish around the structure.

5.8.8 No significant adverse effects have been identified during construction.

Compensation of operational effects

5.8.9 Positive benefits on all aquatic ecology receptors as a result of the water quality improvements are predicted (Section 5.6). Nevertheless, even with the mitigation measures described above there would be a permanent loss of approximately 1.2ha of intertidal and subtidal habitat which also represents a loss of spawning, feeding and nursery habitat for fish. These are considered to be moderate adverse (and therefore significant) effects for which compensation would be provided.

5.8.10 The approach to identifying appropriate compensation has been first to consider the functionality of the habitats to be lost, both as physical habitats and for the populations of species which depend on them, and then to identify the most appropriate way of re-providing those functions. For example, in terms of functionality for fish the sub-tidal gravel habitats in the Upper Tideway offer spawning sites for dace and smelt, whilst the intertidal sand and gravel foreshore habitats offer feeding, nursery and migratory habitat for a range of tidal Thames fish populations.

5.8.11 There are limited opportunities for habitat creation within the inner London area and hence like for like replacement is considered neither practical or necessary given that the overall objective of the project is to deliver environmental benefits to the tidal Thames.

5.8.12 The Thames Tideway Tunnel Biodiversity Technical Working Group were consulted on potential habitat compensation schemes throughout the assessment area (para. 5.3.7 and 5.3.8). Approximately 40 schemes, ranging from the removal of tidal sluices to river restoration projects were identified by the project team and stakeholders. An initial feasibility assessment was conducted for each scheme based on factors such as the delivery of ecological benefit, engineering deliverability and proportionate cost.

5.8.13 Priority was given to schemes which could be incorporated within the existing limits of land to be acquired or used (LLAU) for the project since these would be delivered within the application.

5.8.14 Priority was also given to schemes on the creeks which are tidal reaches of watercourses, such as the River Wandle and the Beverley Brook which drain into the Thames Upper and Thames Middle zones of the tidal Thames. The tidal creeks have a disproportionately higher value than the main tidal Thames because they offer a refuge, particularly for juvenile fish, from strong current velocities. An intertidal terrace has been incorporated into the scheme at the Dormay Street site which lies on the Bell Lane Creek, a tidal distributary in the lower reaches of the River Wandle. Details of the scheme are provided in para. 5.8.15 to 5.8.17.

Intertidal terrace at Dormay Street.

5.8.15 During fish baseline surveys undertaken in May 2011 a number of freshwater species were recorded within the Bell Lane Creek, including stone loach (*Barbatula barbatula*), a species which was not recorded elsewhere on the tidal Thames. Given the value of the fish community at this site, and its location adjacent to the Thames Tideway Tunnel project site at Dormay Street, priority was given to incorporating an intertidal terrace at this location. The intertidal terrace at Dormay Street is incorporated into the LLAU and described in Section 3 of Vol 8.

5.8.16 A 36m section of the river wall adjoining the Dormay Street site is in poor condition and requires strengthening. There is insufficient space within the site boundary to accommodate a terrace when the river wall is strengthened at the commencement of construction. However, the wall would be built in such a way that the upper section set back in order to form the terrace. The terrace would be 2.9m wide and would extend along 36m of strengthened river wall.

5.8.17 The design of the terrace would be based on best practice guidance such as the Environment Agency's *Estuary Edges Design Guidance*[88]. It would be designed to maximise inundation between the Mean High Water Spring and the Mean High Water Neap tidal levels in order to ensure that intertidal vegetation would establish.

Further compensation measures

Campshed removal

5.8.18 There is a redundant campshed structure adjacent to the stretch of river wall that would require replacement at Dormay Street (Vol 3 Plate 5.8.1). Although it is not included within the project, measures would be progressed to secure the removal of this as a separate consent. Removal of the campshed would expose the underlying river bed thus creating additional habitat for fish and invertebrates.

Vol 3 Plate 5.8.1 Aquatic ecology - Existing campshed at Dormay Street

Fish passage schemes

5.8.19 Many of the tributary watercourses of the tidal Thames are wholly or partially blocked by operational and redundant weirs and sluices. Relatively minor modifications to these structures offer a cost effective means of facilitating access for fish to upstream spawning grounds. Furthermore, as signatory to the EU Eel Regulations, the UK has an obligation to enable passage for 40% of adult eels to their spawning grounds.

5.8.20 By removing or bypassing the structures which currently lie at the interface between the tidal and freshwater reaches of tributary watercourses access would be improved to new upstream habitats. It would provide the added benefit of increasing the resilience of fish populations to pollution events. For example, when a CSO event occurs fish would be able to move up into these tributary watercourse temporarily in order to escape the acute effects of hypoxia. Furthermore, tributary watercourses support valuable ‘reservoirs’ of diadromous and freshwater fish. With improved access to the main tidal Thames these populations would be able to colonise more readily.

5.8.21 In discussion with the Environment Agency (December 2012 – see para. 5.3.9), four structures on tributary watercourses have been identified for which modifications could be made to allow the free passage of fish. They are:

a. Bell Lane Sluice, River Wandle (TQ 37409 76770)

b. Lewisham College Tidal Weir, Ravensbourne River (TQ 37419 77017)

c. Broadway Fields, Ravensbourne River (TQ 37441 76797)

d. Kidds Mill Sluice, Duke of Northumberland River (TQ 16588 75952).

5.8.22 An initial site visit has been made to each of these schemes by a fisheries expert and possible options for modifications identified. Further feasibility studies are ongoing and would be progressed during the application determination period.

5.8.23 A commitment would be made as part of the Thames Tideway Tunnel project to implement two of these schemes. The selection of the schemes would be based on the ecological benefits, engineering feasibility, flood risk considerations and proportionate cost.

Consideration of other compensation measures

5.8.24 A review was undertaken to consider the potential for incorporating intertidal terraces into the permanent structures above the 4m wide ship protection zone at the other foreshore sites. However, the ship protection zone is required to extend to the full height of the structures to safeguard the proposed infrastructure.

5.8.25 The potential for removing existing aprons at sites where the CSO would either not spill or spill very infrequently has also been considered. The benefit of this would be to expose the underlying foreshore thus offsetting some of the losses associated with the permanent works. However, in many cases the existing aprons have been found to be already buried and removal of the aprons would cause disturbance to existing habitats and potentially release of contaminants. In addition, the force of sporadic but high volume discharges could generate significant scour effects if adequate river bed protection is not in place.

5.9 Residual effects assessment

Construction effects

5.9.1 Residual effects during construction are considered to be no more than minor adverse and therefore not significant.

Operational effects

5.9.2 As stated in the Engagement section, a balance sheet has not been used to evaluate compensation measures. This is because improvements to water quality resulting in functional benefits to species and populations cannot be readily quantified in terms of physical area.

5.9.3 Prior to the implementation of compensation measures significant adverse effects have been identified on tidal Thames habitats and fish populations due to permanent landtake. The residual effects on these and other receptors are discussed below.

5.9.4 The intertidal terraces on the main tidal Thames at Albert Embankment Foreshore and on the Bell Lane Creek at Dormay Street would create new intertidal habitat. The terraces would offer vegetated high tide habitat, which is uncommon in the context of the main tidal Thames. Tidal creeks such as the Bell Lane Creek are particularly important for fish and are identified as flag ship habitats in the *Tidal Thames Habitat Action Plan* (Thames Estuary Partnership, undated). The terraces therefore potentially offer higher value habitat for both fish and invertebrates than the existing intertidal and subtidal habitat that is being lost.

5.9.5 Nevertheless, there would be a residual loss of intertidal and subtidal habitat of 1.2 ha due to permanent landtake. This represents approximately 0.05% of the River Thames and Tidal Tributaries SINC (Grade M). Loss at this scale is not considered to affect the integrity of either the habitats themselves or the populations that they support although it is contrary to the Environment Agency's *Tidal Rivers Encroachment Policy*6 . The water quality benefits arising from the Thames Tideway Tunnel project would help to offset this by improving the functionality of the habitats as a feeding resource for fish and invertebrates and a spawning habitat for dace and smelt.

5.9.6 The residual effects on fish would be beneficial. The design measures at Dormay Street and Albert Embankment Foreshore combined with the compensation measures (removal of the campshed at Dormay Street and two fish passage schemes which facilitate access to new habitats in the upper reaches of tributary watercourses) are considered to offset significant adverse effects on fish populations associated with permanent landtake. The improvements in water quality which would occur with the Thames Tideway Tunnel project would lead to increases in fish populations. By improving access to tributary watercourses fish populations are likely to be enhanced across a wider proportion of the catchment than would otherwise occur. The water quality improvements and the compensation measures are thus acting in combination to increase the benefit for fish. The measure would also contribute to objectives set under the Eel Regulations 2009 to facilitate access for eels to 40% of tributary watercourses.

5.9.7 The DO improvements would ensure that all existing fish populations, including DO sensitive species would be sustainable in the long term and ensure that water quality objectives under the Water Framework Directive and Urban Waste Water Treatment Directive are met. The Thames Tideway Tunnel project is also identified as one of the measures required to ensure that the conservation objective to maintain smelt in the Thames Estuary MCZ are met (Vol 3 Appendix C.5).

5.9.8 The DO improvements would give rise to positive benefits on other aquatic ecology receptors including invertebrates and algae and would contribute to the recovery of these groups within the tidal Thames.

5.10 Project-wide effects assessment summary

Vol 3 Table 5.10.1 Aquatic ecology – summary of construction assessment

Receptor	Effect	Significance of effect	Mitigation	Significance of residual effect
Designated sites and habitats	Loss of intertidal and subtidal habitat due to temporary landtake	Minor adverse	None	Minor adverse
	Disturbance and consolidation of intertidal and subtidal habitat	Minor adverse	None	Minor adverse
	Changes to intertidal and subtidal habitat due to scour and accretion	Minor adverse	None	Minor adverse
Marine mammals	Interference with the migrations of marine mammals within the tidal Thames	Minor adverse	None	Negligible
Fish	Loss of spawning, feeding, resting and nursery habitat for fish due to temporary landtake (assuming option A at Carnwath Road Riverside)	Minor adverse	None	Minor adverse
	Loss of spawning, feeding, resting and nursery habitat for fish due to temporary landtake (assuming option B at Carnwath Road Riverside)	Moderate adverse	None	Moderate adverse
	Loss of feeding, resting and nursery habitat for fish due to sediment consolidation and disturbance	Minor adverse effect	None	Negligible
	Loss of feeding, resting, spawning and nursery habitat due to scour	Minor adverse	None	Minor adverse
	Interference with migratory movements of fish	Negligible	None	Negligible
	Effect of waterborne noise and vibration on fish due to piling operations	Minor adverse	None	Minor adverse

Receptor	Effect	Significance of effect	Mitigation	Significance of residual effect
	Effect of waterborne noise and vibration on fish due to dredging and barge movements	Minor adverse	None	Minor adverse
	Water quality effects on fish and reduction in water column visibility due to suspended sediment	Negligible	None	Negligible
Invertebrates	Direct mortality of invertebrates due to temporary landtake and disturbance and consolidation of sediment.	Minor adverse	None	Minor adverse
	Loss of burrowing and feeding habitat for invertebrates due to landtake	Minor adverse	None	Minor adverse
	Loss of feeding/burrowing habitat for invertebrates due to sediment consolidation and disturbance	Negligible	None	Negligible
	Loss of feeding and burrowing habitat for invertebrates due to scour and accretion	Negligible	None	Negligible
	Blanketing of feeding areas for invertebrates and reduction in water column visibility due to accretion.	Negligible	None	Negligible
	Increase in abundance/distribution of invasive species	Negligible	None	Negligible
Algae	Loss of algal communities due to temporary landtake	Negligible	None	Negligible
	Restricted algal growth due to suspended sediment	Negligible	None	Negligible

Vol 3 Table 5.10.2 Aquatic ecology – summary of operational assessment

Receptor	Effect	Significance of effect		Mitigation	Significance of residual effect	Compensation
		Year 1	Year 6			
Designated sites and habitats	Improvements in DO concentration					
	Thames Estuary and Marshes SPA and Inner Thames Marshes SSSI	Negligible	Negligible	None	Negligible	
	Thames and Tidal tributaries SINC (Grade M)	Moderate beneficial	Moderate beneficial	None	Moderate beneficial	
	Chiswick Ayot and Isleworth Ayot.	Minor beneficial	Minor beneficial	None	Minor beneficial	
	Other non-statutory sites	Negligible	Negligible	None	Negligible	
	Reduction in sediment nutrient levels and sewage derived litter	Minor beneficial	Minor beneficial	None	Minor beneficial	
	Thames Estuary and Marshes SPA and Inner Thames Marshes SSSI	Negligible	Negligible	None	Negligible	
	Thames and Tidal tributaries SINC (Grade M), Chiswick Ayot and Isleworth Ayot.	Minor beneficial	Minor beneficial	None	Minor beneficial	
	Other non-statutory sites	Negligible	Negligible	None	Negligible	
	Permanent loss of intertidal and subtidal habitat	Moderate adverse	Moderate adverse	No measures to prevent or reduce	Moderate adverse	On and off-site compensation measures proposed to offset

Receptor	Effect	Significance of effect		Mitigation	Significance of residual effect	Compensation
		Year 1	Year 6			
				effects.		adverse effects
	Thames and Tidal tributaries SINC (Grade M) only	Moderate adverse	Moderate adverse	No measures to prevent or reduce effects.	Moderate adverse	On and off-site compensation measures proposed to offset adverse effects.
	Modification of intertidal and subtidal habitats	Minor adverse	Minor adverse	None	Minor adverse	
Marine mammals	Increase in the number and/or change in the distribution of marine mammals.	Negligible effect	Minor positive	None	Negligible	
Fish	Reduction in the occurrence of low dissolved oxygen related fish mortalities.	Moderate positive	Moderate positive	None	Moderate beneficial	
	Increase in the distribution of pollution sensitive fish species.	Minor positive	Minor positive	None	Minor beneficial	
	Permanent loss of intertidal spawning, feeding and resting habitat for fish.	Moderate adverse	Moderate adverse	No measures to prevent or reduce effects.	Moderate adverse	On and off-site compensation measures proposed to offset adverse effects.
	Modification of intertidal and subtidal habitats for fish	Minor adverse	Minor adverse	None	Negligible to minor beneficial	
	Interference with migratory movements of fish due to blockage of the intertidal area by	Negligible		None	Negligible	

Receptor	Effect	Significance of effect		Mitigation	Significance of residual effect	Compensation
		Year 1	Year 6			
	permanent structures.					
Invertebrates	River wide improvements in invertebrate diversity and abundance due to improved water quality	Moderate beneficial	Moderate beneficial	None	Moderate beneficial	
	Increase in the distribution of pollution sensitive invertebrate species due to improved water quality.	Minor beneficial	Minor beneficial	None	Minor beneficial	
	Permanent loss of intertidal feeding and burrowing habitat for invertebrates due to landtake.	Minor adverse	Minor adverse	None	Minor adverse	
	Modification of intertidal and subtidal habitats for invertebrates by scour protection	Minor adverse	Minor adverse	None	Minor adverse	
Algae	Localised improvements in diversity and abundance	Minor beneficial	Minor beneficial	None	Minor beneficial	

5.11 Summary of significant effects at all sites

5.11.1 Significant adverse effects on aquatic ecology have been identified at a number of sites. This is due to the loss of habitat during construction and operation and to disturbance effects during construction. There would be also be significant beneficial effects once the Thames Tideway Tunnel project is operational due to a reduction in the occurrence of dissolved oxygen related fish mortalities. Vol 3 Table 5.11.1 provides a summary of the significant effects identified at individual sites across the project. Mitigation measures have been identified and are described where relevant within Vols 4 to 27. These effects are also included in the project wide assessment and do not constitute additional effects.

Vol 3 Table 5.11.1 Aquatic ecology – summary of likely significant effects at all sites

Significance of effect	Receptor	Description of effect	Sites with significant effects (pre-mitigation)	Sites with significant residual effects
Construction - adverse	Designated sites and habitats	Loss of intertidal and subtidal habitat due to temporary landtake.	Albert Embankment Foreshore (Vol 16 Section 5) Chambers Wharf (Vol 20 Section 5)	Albert Embankment Foreshore (Vol 16 Section 5) Chambers Wharf (Vol 20 Section 5)
	Fish	Increase in the occurrence of dissolved oxygen related fish mortalities.	Abbey Mills Pumping Station (Vol 25 Section 5)	Abbey Mills Pumping Station (Vol 25 Section 5)
		Changes in the distribution of pollution sensitive fish.	Abbey Mills Pumping Station (Vol 25 Section 5)	Abbey Mills Pumping Station (Vol 25 Section 5)
Operation - adverse	Designated sites and habitats	Permanent loss of intertidal habitat	Albert Embankment Foreshore (Vol 16 Section 5) Blackfriars Bridge Foreshore (Vol 18 Section 5) Chelsea Embankment Foreshore (Vol 13 Section 5) Heathwall Pumping Station (Vol 15 Section 5) King Edward Memorial Park Foreshore (Vol 21 Section 5) Putney Embankment Foreshore (Vol 7	Albert Embankment Foreshore (Vol 16 Section 5) Blackfriars Bridge Foreshore (Vol 18 Section 5) Chelsea Embankment Foreshore (Vol 13 Section 5) Heathwall Pumping Station (Vol 15 Section 5) King Edward Memorial Park Foreshore (Vol 21 Section 5) Putney Embankment Foreshore (Vol 7

Significance of effect	Receptor	Description of effect	Sites with significant effects (pre-mitigation)	Sites with significant residual effects
			Section 5) Victoria Embankment Foreshore (Vol 17 Section 5)	Section 5) Victoria Embankment Foreshore (Vol 17 Section 5)
	Fish	Permanent loss of intertidal feeding and resting habitat for fish due to landtake.	Chelsea Embankment Foreshore (Vol 13 Section 5) King Edward Memorial Park Foreshore (Vol 21 Section 5) Putney Embankment Foreshore (Vol 7 Section 5)	Chelsea Embankment Foreshore (Vol 13 Section 5) King Edward Memorial Park Foreshore (Vol 21 Section 5) Putney Embankment Foreshore (Vol 7 Section 5)
Operation - beneficial	Designated sites and Habitats	Creation of an area of new intertidal habitat	Dormay Street (Vol 8 Section 5)	Dormay Street (Vol 8 Section 5)
	Fish	Permanent gain of intertidal feeding and resting habitat for fish due to new habitat creation.	Dormay Street (Vol 8 Section 5)	Dormay Street (Vol 8 Section 5)
		Reduction in the occurrence of dissolved oxygen related fish mortalities.	Acton Storm Tanks (Vol 4 Section 5) Barn Elms (Vol 6 Section 5) Chelsea Embankment Foreshore (Vol 13 Section 5) Cremorne Wharf Depot (Vol 12 Section 5) Deptford Church Street (Vol 23 Section 5)	Acton Storm Tanks (Vol 4 Section 5) Barn Elms (Vol 6 Section 5) Chelsea Embankment Foreshore (Vol 13 Section 5) Cremorne Wharf Depot (Vol 12 Section 5) Deptford Church Street (Vol 23 Section 5)

Significance of effect	Receptor	Description of effect	Sites with significant effects (pre-mitigation)	Sites with significant residual effects
			Dormay Street (Vol 8 Section 5) Earl Pumping Station (Vol 22 Section 5) Falconbrook Pumping Station (Vol 11 Section 5) Greenwich Pumping Station (Vol 24 Section 5) Hammersmith Pumping Station (Vol 5 Section 5) Heathwall Pumping Station (Vol 15 Section 5) King Edward Memorial Park Foreshore (Vol 21 Section 5) King George's Park (Vol 9 Section 5) Putney Embankment Foreshore (Vol 7 Section 5)	Dormay Street (Vol 8 Section 5) Earl Pumping Station (Vol 22 Section 5) Falconbrook Pumping Station (Vol 11 Section 5) Greenwich Pumping Station (Vol 24 Section 5) Hammersmith Pumping Station (Vol 5 Section 5) Heathwall Pumping Station (Vol 15 Section 5) King Edward Memorial Park Foreshore (Vol 21 Section 5) King George's Park (Vol 9 Section 5) Putney Embankment Foreshore (Vol 7 Section 5)
		Increase in the distribution of pollution sensitive fish species.	Acton Storm Tanks (Vol 4 Section 5) Barn Elms (Vol 6 Section 5) Chelsea Embankment Foreshore (Vol 13 Section 5) Cremorne Wharf Depot (Vol 12 Section 5) Deptford Church Street (Vol 23 Section 5) Dormay Street (Vol 8 Section 5) Earl Pumping Station (Vol 22 Section 5) Falconbrook Pumping Station (Vol 11 Section 5) Greenwich Pumping Station (Vol 24 Section 5) Hammersmith Pumping Station (Vol 5 Section 5)	Acton Storm Tanks (Vol 4 Section 5) Barn Elms (Vol 6 Section 5) Chelsea Embankment Foreshore (Vol 13 Section 5) Cremorne Wharf Depot (Vol 12 Section 5) Deptford Church Street (Vol 23 Section 5) Dormay Street (Vol 8 Section 5) Earl Pumping Station (Vol 22 Section 5) Falconbrook Pumping Station (Vol 11 Section 5) Greenwich Pumping Station (Vol 24 Section 5) Hammersmith Pumping Station (Vol 5 Section 5)

Significance of effect	Receptor	Description of effect	Sites with significant effects (pre-mitigation)	Sites with significant residual effects
			Heathwall Pumping Station (Vol 15 Section 5) King Edward Memorial Park Foreshore (Vol 21 Section 5) King George's Park (Vol 9 Section 5) Putney Embankment Foreshore (Vol 7 Section 5)	Heathwall Pumping Station (Vol 15 Section 5) King Edward Memorial Park Foreshore (Vol 21 Section 5) King George's Park (Vol 9 Section 5) Putney Embankment Foreshore (Vol 7 Section 5)
		Improvement in the quality of foraging habitat	Acton Storm Tanks (Vol 4 Section 5) Barn Elms (Vol 6 Section 5) Chelsea Embankment Foreshore (Vol 13 Section 5) Cremorne Wharf Depot (Vol 12 Section 5) Deptford Church Street (Vol 23 Section 5) Dormay Street (Vol 8 Section 5) Earl Pumping Station (Vol 22 Section 5) Falconbrook Pumping Station (Vol 11 Section 5) Greenwich Pumping Station (Vol 24 Section 5) Hammersmith Pumping Station (Vol 5 Section 5) Heathwall Pumping Station (Vol 15 Section 5) King Edward Memorial Park Foreshore (Vol 21 Section 5) King George's Park (Vol 9 Section 5) Putney Embankment Foreshore (Vol 7) Section 5	Acton Storm Tanks (Vol 4 Section 5) Barn Elms (Vol 6 Section 5) Chelsea Embankment Foreshore (Vol 13 Section 5) Cremorne Wharf Depot (Vol 12 Section 5) Deptford Church Street (Vol 23 Section 5) Dormay Street (Vol 8 Section 5) Earl Pumping Station (Vol 22 Section 5) Falconbrook Pumping Station (Vol 11 Section 5) Greenwich Pumping Station (Vol 24 Section 5) Hammersmith Pumping Station (Vol 5 Section 5) Heathwall Pumping Station (Vol 15 Section 5) King Edward Memorial Park Foreshore (Vol 21 Section 5) King George's Park (Vol 9 Section 5) Putney Embankment Foreshore (Vol 7 Section 5)

Significance of effect	Receptor	Description of effect	Sites with significant effects (pre-mitigation)	Sites with significant residual effects
	Invertebrates	Localised improvements in invertebrate diversity and abundance.	Acton Storm Tanks (Vol 4 Section 5)	Acton Storm Tanks (Vol 4 Section 5)
		Increase in the distribution of pollution sensitive invertebrate species.	Acton Storm Tanks (Vol 4 Section 5)	Acton Storm Tanks (Vol 4 Section 5)

References

[1] National Policy Statement for Waste Water February 2012 http://www.defra.gov.uk/publications/2012/02/09/pb13709-waste-water-national-policy-statement/ last accessed January 2013

[2] Environment Agency. *Pollution Prevention Guide 05: Works in, near or liable to affect water courses.* (undated)

[3] CIRIA..C532*: Control of water pollution from construction sites: Guidance for consultants and contractors*. (2001)

[4] *Environment Agency (2009) – Thames River Basin Management Plan*

[5] Thames Water. EIA Scoping Report (2011). Available at: http://www.thamestunnelconsultation.co.uk/document-library/catalogue-view/?c=4-eia-scoping-report

[6] *Environment Agency (Undated)* – National Encroachment Policy for Tidal Rivers and Estuaries.

[7] K. Amoo-Gottfried, pers. comm., in Colclough *et al.*, 2002

[8] Balanced Seas. *Marine Conservation Zone – final recommendations* (September 2011).

[9] Balanced Seas. (2011) See citation above.

[10] Joint Nature Conservation Committee. *UK Biodiversity*. Available at http://jncc.defra.gov.uk/page-1817. Last accessed May 2012.

[11] Thames Estuary Partnership Biodiversity Action Group Tidal Thames Habitat Action Plan. *Thames Estuary Partnership* (undated).

[12] Thames Estuary Partnership Biodiversity Action Group (undated) see citation above

[13] Elliott, M and Taylor, CJL. *The structure and functioning of an estuarine/marine fish community in the Forth estuary, Scotland* (1989). Proc. 21st European Marine Biological Symposium (Gdansk). Polish Academy of Sciences, Institute of Oceanology, Warsaw, Poland, 227-240.

[14] Araujo, F.G., Williams, W.P., Bailey, R.G. 2000. Fish assemblages as indicators of water quality in the middle Thames Estuary, England (1980-1989). Estuaries, 23(3): 305 317.

[15] Beek, F.A. van, Rijnsdorp, A.D., and De Clerck, R. 1989. Monitoring juvenile stocks of flatfish in the Wadden Sea and coastal areas of the southeastern North Sea. Helgoländer Meeresuntersuchungen 43: 461-477.

[16] Thomas, M. (1998). Temporal changes in the movements and abundance of Thames estuary fish populations. In *A Rehabilitated Estuarine Ecosystem: The Environment and Ecology of the Thames Estuary* (Attrill, M. J., ed.), pp. 115–139. London: Kluwer Academic Publishers.

[17] Colclough, S. R., Gray, G., Bark, A. & Knights, B. (2002). Fish and fisheries of the tidal Thames: management of the modern resource, research aims and future pressures. *Journal of Fish Biology.* 61(Suppl. A): 64-73.

[18] Joint Nature Conservation Committee (undated) http://jncc.defra.gov.uk/page-5155 last accessed November 2012

[19] Colclough, S. R. (2001). Fish populations of the tidal Thames: a draft summary of data held by the Environment Agency as of March 2001. Environment Agency (Thames Region).

[20] Nature protection: the Convention on the Conservation of European Wildlife and Natural Habitats (Bern Convention) http://www.coe.int/t/e/cultural_co-operation/environment/nature_and_biological_diversity/Nature_protection/

[21] Natural England (2012). http://www.naturalengland.org.uk/ourwork/marine/mpa/mcz/features/species/europeaneel.aspx. Page last accessed August 2012.

[22] Griffiths, A, Ellis, J, Clifton-Dey, D, Machado-Schiaffino, G, Bright, D, Garcia-Vazquez, E, Stevens, J (2011). Restoration versus recolonisation: The origin of Atlantic salmon (*Salmo salar* L.) currently in the River Thames. Biological Conservation 144: 2733-2738.

[23] Colclough *et al* (2002) See citation above

[24] Colclough *et al* (2002) See citation above

[25] Wheeler, AC (1979). The Tidal Thames. The History of a River and its Fishes. Routledge and Kegan Paul, London.

[26] Turnpenny, A.W.H., Clough, S.C., Holden, S.D.J., Bridges, M., Bird, H., O'Keeffe, N.J., Johnson, D., Edmonds, M., Hinks, C. (2004). Thames Tideway Strategy: Experimental Studies on the Dissolved Oxygen Requirements of Fish Consultancy Report no.FCR374/04 to Thames Water Utilities, Ltd. Fawley Aquatic Research, Fawley Southampton, April, 2004. http://www.wfduk.org/LibraryPublicDocs/ThamesTidewayStrategyExperimentalStudiesontheDissolvedOxygenRequirementsofFish [accessed 03.08.09]

[27] Turnpenny, A.W.H., Clough, S.C., Holden, S.D.J., Bridges, M., Bird, H., O'Keeffe, N.J., Johnson, D., Edmonds, M., Hinks, C. (2004). See citation above

[28] Thames Water. *Needs Report. Appendix F Tideway Fisheries Review*. (2010)

[29] Walley W.J. and Hawkes H.A. (1996) A computer-based reappraisal of Biological Monitoring Working Party scores using data from the 1990 River Quality Survey of England and Wales. *Water Research*, **30** (9), 2086-2094.

[30] Walley W.J. and Hawkes H.A. (1997) A computer-based development of the Biological Monitoring Working Party score system incorporating abundance rating, biotope type and indicator value. *Water Research*, **31** (2), 201-210.

[31] Attrill, M.J. (1998) The benthic macroinvertebrate communities of the Thames estuary. A Rehabilitated Estuarine Ecosystem: the environment and ecology of the Thames Estuary (ed. M.J. Attrill), pp. 85–113. Kluwer Academic Publishers, Dordrecht.

[32] Environment Agency, personal communication (2012)

[33] Atrill, M. J. (1998) See citation above.

[34] Peran, A., J. Velasco, and A. Millan. (1999). Life cycle and secondary production of *Caenis luctosa* (Ephemeroptera) in a semiarid stream (Southeast Spain). Hydrobiologia. 400: 187-194.

[35] Costil, K.; Dussart, G. and Daguzan, J. (2001). Parameters structuring populations of aquaticgastropods in the region of Mont Saint-Michel (France). Biodiversity and Conservation,10:1-18.

[36] Dreier H, Tranquilli JH (1981) Reproduction, growth, distribution, and abundance of Corbicula in an Illinois cooling lake. Illinois Natural History Survey Bulletin 32: 378-393

[37] Walley W.J., Grbović J. and Džerosk S. (2001). A reappraisal of saprobic values and indicator weights based on Slovenian river quality data. Wat. Res. 35(18), 4285–4292.

[38] Walley and Hawkes, 1996. See citation above.

[39] Walley and Hawkes, 1997. See citation above.

[40] Mouthon, J (1996). Molluscs and biodegradable pollution in rivers: proposal for a scale of sensitivity of species. Hydrobiologia, 1996, Volume 317: 221-229

[41] Mouthon, J (1996). See citation above.

[42] Queiroga H. (1990). *Corophium multisetosum* (Amphipoda: Corophiidae) in Canal de Mira, Portugal: some factors that affect its distribution. In *Marine Biology* 104, 397-

[43] Mills A. and Fish J.D. (1980). Effects of Salinity and Temperature on *Corophium volutator* and *C. arenarium* (Crustacea: Amphipoda), with Particular Reference to Distribution. In *Marine Biology* 58,153-161

[44] Gérard C., Blanc A., Costil K. (2003). Potamopyrgus antipodarum (Mollusca:Hydrobiidae) in continental aquatic gastropod communities: impact of salinity and trematode parasitism. In *Hydrobiologia* **493:** 167–172, 2003. *Kluwer Academic Publishers.*

[45] Bulnheim I H. -P. and Scholl A. (1981). Genetic Variation Between Geographic Populations of the Amphipods *Gammarus zaddachi* and *G. salinus.* In *Marine Biology* 64, 105-115 (1981)

[46] Bulnheim I H. (1979). Comparative Studies on the Physiological Ecology of Five Euryhaline Gammarus Species. In Oecologia (Bed.) 44, 80-86

[47] Diaz, R. J. and R. Rosenberg. (1995). Marine benthic hypoxia - review of ecological effects and behavioral responses on macrofauna. Oceanography and Marine Biology, Annual Review. 33:245-303.

[48] Jones, L.A., Hiscock, K. & Connor, D.W., (2000). Marine habitat reviews. A summary of ecological requirements and sensitivity characteristics for the conservation and management of marine SACs. Joint Nature Conservation Committee, Peterborough. (UK Marine SACs report.).,

[49] •Bailey-Brock, J.H., Paavo, B., Barrett, B.M., & Dreyer, J. (2002). Polychaete species as organic enrichment indicators from Oahu, Hawaii'i. Pacific Science 156 (4): 459-479.

[50] Bryan, G. W. (1984). Pollution due to heavy metals and their compounds. Mar. Ecol. 5, 1290-1431.

[51] Dean, H.K., (2008). The use of polychaete (Annelida) as indicator species of marine pollution: A review. Rev. Biol. Trop., 56: 11-38.

[52] Attrill, M.J. (1998) See citation above

[53] Chadd, R and Extence, C. *The conservation of freshwater macroinvertebrate populations: a community based classification scheme*. Aquatic Conservation: Marine and Freshwater Ecosystems. (2004) 14: 597-624.

[54] Bratton, J.H. (editor). B*ritish Red Data Books: 3. Invertebrates other than insects*. JNCC, Peterborough (1991).

[55] Shirt, D.B. (editor). *British Red Data Books: 2 Insects*. Peterborough: Nature Conservancy Council (1987).

[56] Lincoln, R.J. (1979). British marine Amphipoda: Gammaridea. British Museum (Natural History): London, UK. ISBN 0-565-00818-8. vi, 658 pp.

[57] Elliott, P. and zu Ermgassen, P. (2008). The Asian clam (*Corbicula fluminea*) in the River Thames, London, England. Aquatic Invasions 3: 54-60.

[58] Tittley I. 2009. The marine algae (seaweeds) of the tidal Thames: a systematic and floristic account. *The London Naturalist* 88: 29-44.

[59] Tittley I. 2009. See citation above

[60] Tittley, I. (2001) Changes in the marine algal flora of the tidal Thames: a millennium review. *The London Naturalist* 80: 135-146.

[61] Tittley I. 2009. See citation above

[62] Tittley I. 1985. Zonation an seasonality of estuarine benthic algae: artificial embankments in the River Thames. *Botanica Marina* 28: 1-8.

[63] Cox E.J. & Tittley I. 2000. *Soft encroachment survey*. Report for Environment Agency, Thames Area. The Natural History Museum, London

[64] Tittley I. & Cox E.J. 1997. *Deptford Creek algal survey*. A report for Creekside Greening and Cleaning , London Borough of Lewisham. The Natural History Museum, London.

[65] Tittley I. 2009. See citation above

[66] Tittley I. 2009. See citation above

[67] Greater London Authority. *London Plan.* Available at www.london.gov.uk/priorities/planning/londonplan. Last accessed May 2012.

[68] Environment Agency *National Encroachment Policy for Tidal Rivers and Estuaries* (2005)

[69] Detailed Scour Assessment – Putney Bridge. HR Wallingford. Report Reference: 100-RG-MDL-WALLI-000028 Rev AC.

[70] Black and Veatch, *Fluvial Scour Study Peer Review*, (2012)

[71] Nedwell J and Edwards B (2002). Measurements of underwater noise in the Arun River during piling at County Wharf, Littlehampton, Report Reference 513 R 0108

[72] Simmonds M, Dolman S and Weilgart L. 2004. Oceans of Noise. A Whale and Dolphin Conservation Society report.

[73] HR Wallingford *Effect of construction activities on sediment supply to Thames Estuary Salt Marshes, Technical Note DDR4704-02,* (2011)

[74] HR Wallingford (2011). See citation above

[75]Nedwell, J. R., Edwards, B., Turnpenny, A.W.H. and Gordon, J. (2004) Fish and Marine Mammals Audiograms: A summary of available information. Subacoustech report ref: 534R0214

[76] Nedwell, A.W.H. Turnpenny, J. Lovell, S.J. Parvin, R. Workman, J.A.L. Spinks & D. Howell. (2007) A validation of the dBht as a measure of the behavioural and auditory effects of underwater noise J.R. Subacoustech Report No. 534R1231

[77] Nedwell J and Edwards B (2002). See citation above.

[78] Nedwell, A.W.H. Turnpenny, J. Lovell, S.J. Parvin, R. Workman, J.A.L. Spinks & D. Howell. (2007) See citation above.

[79] Nedwell J, Turnpenny A, Langworthy J, and Edwards B. 2003. Measurements of underwater noise during piling at the Red Funnel Terminal, Southampton, and observations of its effect on caged fish. Report Reference: 558 R 0207

[80] Environment Agency (2009) River Basin Management Plan, Thames River Basin District. Environment Agency

[81] Verbrugge, L.N.H., Schipper A.M., Huijbregts M.A.J., Van der Velde G., Leuven R.S.E.W. (2011). Sensitivity of native and non-native mollusc species to changing river water temperature and salinity. Biol Invasions. DOI 10.1007/s10530-011-0148-y

[82] URS Scott Wilson (2011). Hardham Tidal Abstraction Scheme 2010 Baseline depressed river mussel survey report

[83] Willing M.J. (2005). River Arun Scoping Study: Targeted survey for the (1) Swollen Spire Snail (Mercuria confusa) and (2) Compressed River Mussel (*Pseudanodonta complanata*)

[84] Willing M.J. (2006). River Arun Scoping Study: Further surveys for the (1) Swollen Spire Snail (Mercuria confusa) and (2) Compressed River Mussel (*Pseudanodonta complanata*) July – October 2006

[85] Joint Nature Conservation Committee (2010) *UK Priority Species data collation Pseudanodonta complanata version 2 updated on 15/12/2010*. Available at http://jncc.defra.gov.uk/_speciespages/534.pdf. Last accessed December 2012.

[86] Mouthon (1996) See citation above.

[87] Bless R. (1981) Beobachtungen zur Muschelfauna des Rheins zwischen Köln und Koblenz. Decheniana 134:234-243.

[88] Environment Agency (undated). *Estuary Edges: Ecological Design Guidance.* Thames Estuary Partnership.

This page is intentionally blank

Thames Tideway Tunnel
Thames Water Utilities Limited

Application for Development Consent

Application Reference Number: WWO10001

Environmental Statement

Doc Ref: **6.2.03**

Volume 3: Project-wide effects assessment

Section 6: Ecology - terrestrial

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

Hard copy available in

Box **17** Folder **A**
January 2013

Thames Tideway Tunnel
Creating a cleaner, healthier River Thames

This page is intentionally blank

Thames Tideway Tunnel

Environmental Statement

Volume 3: Project-wide effects assessment

Section 6: Ecology − terrestrial

List of contents

Page number

List of tables

Page number

This page is intentionally blank

6 Ecology − terrestrial

6.1 Introduction

6.1.1 Project-wide construction and operational effects for terrestrial ecology have been scoped out as explained in Vol 2 Section 6.8. This is on the basis that no significant effects are anticipated during either construction or operation beyond those assessed at a site level.

6.1.2 This section nevertheless presents details of engagement, an overview of the reasons why project-wide effects (as defined in this *Environmental Statement*) have been scoped out and a summary of the significant effects identified at individual sites across the project.

6.1.3 Screening of the project under the Conservation of Habitats and Species Regulations 2010 (The Habitats Regulations 2010) is reported separately in the *Habitat Regulations Assessment: No Significant Effects Report* that accompanies the application for development consent.

6.1.4 Project-wide likely significant effects on aquatic ecology are reported in Section 5 of this volume.

6.2 Engagement

6.2.1 Vol 2 documents the overall engagement which has been undertaken in preparing the *Environmental Statement*. Specific comments relevant to the project-wide assessment of effects on terrestrial ecology are presented in Vol 3 Table 6.2.1.

Vol 3 Table 6.2.1 Terrestrial ecology – stakeholder engagement

Organisation	Comment	Response
Environment Agency (Biodiversity Workshop – July 2012)	Queried whether the assessment considers effects on confluences and creeks, and asked whether the availability of high-tide roosts for birds was being assessed as an in-combination disturbance. There would be hot spots for birds that use old structures to roost, particularly near the creeks. The project could result in the potential loss of the best sites.	Works would be undertaken near to the confluence of the River Thames with the Beverley Brook at Barn Elms, and with Chelsea Creek at Cremorne Wharf Depot. Works are also proposed adjacent to Deptford Creek at Greenwich Pumping Station, within and adjacent to Bell Lane Creek at Dormay Street, and adjacent to the Channelsea River and within the Prescott Channel at Abbey Mills. A wintering birds survey has been undertaken with a survey area covering the site and 250m up and down stream. No significant adverse effects on wintering birds have been identified within the site-assessments as the impacts of habitat loss and disturbance are considered to be minimal. The foreshore areas affected are small relative to the availability of foreshore along the River Thames. Disturbance and displacement across the river already occurs due to the activities of people and boats along the River Thames. At Abbey Mills, where the Lee Tunnel has been under construction, surveys have been undertaken and species have still been recorded resting on vegetation adjacent to the site. It is therefore unlikely that effects will be significant at the Cremorne Wharf Depot site for example, where works are to be undertaken close to the confluence of the River Thames with the Channelsea Creek. Birds associated with one site are unlikely to also be associated with other proposed sites other than at Heathwall and Kirtling Street where these sites are adjacent to each other. Therefore, there are unlikely to be in-combination effects on the same birds or species between sites. The effects of both Kirtling and Heathwall in-combination are assessed each both site assessments for these sites. Some existing structures that provide high tide roosts would be affected at some sites. However, relative to the availability of these features along the River Thames any losses would be very small and are unlikely to result in significant adverse effects on wintering bird populations.

6.3 Overview

6.3.1 Effects on terrestrial ecology would mainly relate to habitats and species affected by temporary and permanent land take. Where there is potential for impacts on highly mobile species such as birds and bats, the extent of these impacts would be localised and it is considered unlikely to affect the integrity of populations across the project area.

6.3.2 In addition, underground tunnelling activities associated with the construction and operation of the main and connection tunnels would take place at considerable depth and so would not have an effect on above-ground habitats and / or species.

6.3.3 Therefore no project-wide assessment has been undertaken for this topic.

6.4 Summary of significant effects at all sites

6.4.1 Significant adverse effects on terrestrial ecology have been identified at Beckton Sewage Treatment Works due to the permanent loss of habitat of local value on site. Mitigation measures for adverse effects at Beckton Sewage Treatment Works are described in Vol 26 Section 6. However, with mitigation in the form of replacement planting, the likely effect would be **negligible** and not significant. Vol 3 Table 6.4.1 provides a summary of the significant effects identified at individual sites across the project.

6.4.2 As no significant adverse effects are anticipated at any other site, no mitigation measures have been proposed and therefore the significance of residual effects would remain unchanged at these sites. As explained in Section 6.3 above, effects identified at individual sites would not result in project-wide effects, (as defined in this *Environmental Statement*) when considered together across the project area.

6.4.3 No significant operational effects are predicted during the operation of the Thames Tideway Tunnel project.

Vol 3 Table 6.4.1 Terrestrial ecology – summary of significant effects at individual sites

Significance of effect	Receptor	Description of effect	Sites with significant effects (pre-mitigation)	Sites with significant residual effects
Construction – adverse	Habitat	Permanent loss of habitat	Beckton Sewage Treatment Works (see Vol 26 Section 6)	None
Construction – beneficial	Habitat	Increase in habitat resource	Falconbrook Pumping Station (see Vol 11 Section 6)	Falconbrook Pumping Station (see Vol 11 Section 6)
	Bats	Increase in bat populations	Abbey Mills Pumping Station – (see Vol 25 Section 6) Acton Storm Tanks (see Vol 4 Section 6) Barn Elms (see Vol 6 Section 6) Hammersmith Pumping Station (see Vol 5 Section 6)	Abbey Mills Pumping Station – (see Vol 25 Section 6) Acton Storm Tanks (see Vol 4 Section 6) Barn Elms (see Vol 6 Section 6) Hammersmith Pumping Station (see Vol 5 Section 6)
	Breeding birds	Increase in bird populations due to the provision of nesting boxes	Abbey Mills Pumping Station (see Vol 25 Section 6)	Abbey Mills Pumping Station (see Vol 25 Section 6)
	Black Redstart	Increase in population due to provision of nest sites for black redstart.	Carnwath Road Riverside (see Vol 10 Section 6)	Carnwath Road Riverside (see Vol 10 Section 6)
	Invertebrates	Increase in the number of nationally and locally notable species present on site.	Acton Storm Tanks (see Vol 4 Section 6) Barn Elms (see Vol 6 Section 6)	Acton Storm Tanks (see Vol 4 Section 6) Barn Elms (see Vol 6 Section 6)

Thames Tideway Tunnel
Thames Water Utilities Limited

Application for Development Consent

Application Reference Number: WWO10001

Environmental Statement

Doc Ref: **6.2.03**

Volume 3: Project-wide effects assessment

Section 7: Historic environment

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

Hard copy available in

Box **17** Folder **A**
January 2013

Thames Tideway Tunnel
Creating a cleaner, healthier River Thames

This page is intentionally blank

Thames Tideway Tunnel

Environmental Statement

Volume 3: Project-wide effects assessment

Section 7: Historic environment

List of contents

Page number

List of tables

Page number

This page is intentionally blank

7 Historic environment

7.1 Introduction

7.1.1 This section presents the findings of the assessment of the likely significant project-wide effects of construction and tunnelling induced ground movement on the historic environment and designated heritage assets.

7.1.2 The ground movements caused by the tunnelling are generally settlement whereas surface excavations can result in both settlement and ground heave. Heave can be caused when materials are removed allowing the *in situ* ground to rebound elastically. The project-wide effects relating to ground movement outside the individual sites are only caused by tunnelling.

7.1.3 The settlement generated by the tunnelling has the potential to affect the designated heritage assets within the affected areas above the tunnels.

7.1.4 The construction works at individual sites also have the potential to affect the designated heritage assets, including the effects of ground movement. These effects are assessed in the historic environment sections of each site assessment (Vols 4 to 27). They are also included for ease of reference within the project-wide assessment.

7.1.5 The designated heritage assets assessed include listed buildings, listed bridges, a listed tunnel, and listed river walls, which all fall under the classification of listed buildings[1], and scheduled monuments along the route.

7.1.6 The proposed development would generate ground movement from tunnelling and construction during the construction phase. Settlement generally continues for some time after the completion of construction activities that generate it and would continue into the period of the tunnel's operation. As the settlement is instigated by the construction activity, the effects are all assessed within the construction phase. For this reason only information relating to construction is presented in the assessment. While there is therefore no operational phase assessment, it is recognised that the existing Bazalgette sewage system is a significant element in the structure of London.

7.1.7 Bazalgette's sewage system is of at least national significance and has shaped the development of central London from the mid 19th century. Its characteristic structures provided a thematic link to the Thames embankments in central London, where none existed previously. The monumental and more homogeneous character that it provided to the Thames helped to augment the existing grandeur of central London, providing it with a cutting edge sewer system and underground railway and setting the tone of the city as a world trade hub and the centre of the empire. The Thames Tideway Tunnel structures are designed to adapt and augment Bazalgette's system, thus preserving its significance and providing it with new lease of life. Lots Road, Shad Thames and

Greenwich Pumping Stations would also be better used and better integrated within the system, thus securing their futures. The use of design themes, such as the unified design of the vent columns, and quality materials would build on Bazalgette's approach. The adaptations to parts of the river walls and buildings represent small interventions to the system as a whole and its structures. The foreshore structures at Chelsea Embankment Foreshore, Victoria Embankment Foreshore and Blackfriars Bridge Foreshore would provide new viewing platforms from which to appreciate Bazalgette's embankments and the formal townscapes that they created. In relation to preserving and enhancing the significance of Bazalgette's sewer system, and providing it with a more secure future, the proposals would overall be beneficial.

7.1.8 There are no construction or operational project-wide effects on the setting of heritage assets from tunnelling as all the tunnelling works outside the sites would be below ground and have no impact on setting. No further assessment of setting has thus been undertaken.

7.1.9 The construction works and proposed above ground structures within work sites that would impact the settings of heritage assets beyond the sites have been assessed. These are assessed within the site assessments (see Vols 4 to 27).

7.1.10 Relevant plans and figures for the project-wide assessment are contained in a separate volume (Vol 3 Project-wide effects assessment figures).

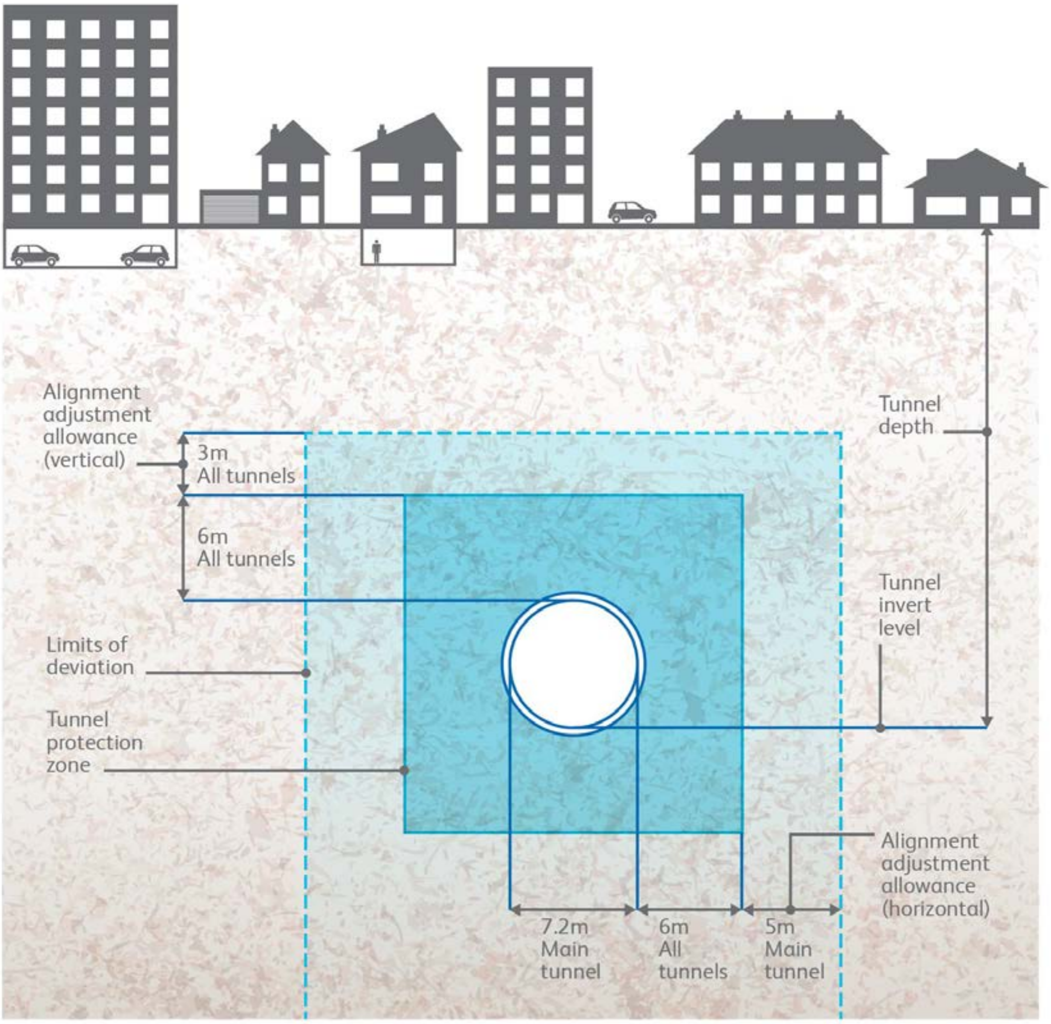
7.2 Proposed development relevant to the historic environment

7.2.1 The proposed development is described in Section 3 of this volume. The specific elements of the proposed development relevant to the effects of demolition, tunnelling and construction induced ground movement on the historic environment are as follows.

Construction

7.2.2 The alignment of the main and connection tunnels would lie within limits of deviation (see separate volume of figures – Section 1). The limits of deviation allow for the tunnel and its lining, a tunnel protection zone and an ‘alignment adjustment’ as illustrated schematically in Vol 3 Plate 7.2.1.

Vol 3 Plate 7.2.1 Historic environment - tunnel section showing limits of deviation



This diagram is indicative only and not to scale

7.2.3 The principles illustrated in Vol 3 Plate 7.2.1 apply to all tunnels forming part of the Thames Tideway Tunnel (ie, the main tunnel and connection tunnels), but the overall width of the limit of deviation varies for the connection tunnels as shown on the works plans and sections (see separate volume of figures – Section 1). The tunnel centreline shown in Vol 3 Plate 7.2.1 lies in the centre of the horizontal limit of deviation and is the assumed tunnel centreline for assessment purposes. The approach to assessing the effect of moving the tunnel centreline within the limits of deviation is explained further below.

7.2.4 The proposed 'alignment adjustment' allows for finalisation of construction methodology, construction tolerances, minor adjustments to increase clearances to existing assets, unforeseen obstructions and detailed design of tunnel linings.

7.2.5 At the western end the route of the main tunnel would take the shortest practical line from Acton Storm Tanks to the River Thames. To the east of this it would stay beneath the river, running in between the supports of the

River Thames bridges, as far east as Rotherhithe. It would then divert from beneath the River Thames to the northeast from King Edward Memorial Park Foreshore where it would run beneath the Limehouse Cut and terminate at Abbey Mills Pumping Station.

7.2.6 The main tunnel would be approximately 25km long with the first 6.9km having a nominal internal diameter of 6.5m and the remaining section a nominal internal diameter of 7.2m. The approximate depth of the main tunnel would range from 30m in west London to 65m in the east at Abbey Mills Pumping Station. A number of additional connection tunnels ranging in nominal internal diameter from 2.2m to 5.0m are required to connect from the existing combined sewer overflows (CSOs) drop shaft to the main tunnel.

7.2.7 The main tunnel runs mainly beneath the River Thames at depths of up to approximately 50m below the river bed. The route of the tunnel has been designed to minimise the impact on buildings and third party infrastructure, by keeping under the river, away from the river banks and thus avoiding built-up areas. Where the tunnel connects to a foreshore based drop shaft this is not possible and the tunnel diverts closer to the river walls.

7.2.8 The effects of settlement generated by the Frogmore connection tunnel and the Greenwich connection tunnel, which connect to the main tunnel from the south, are also assessed.

7.2.9 The main tunnel would be constructed using an Earth Pressure Balance Machine (EPBM) whilst it is in the London Clay, the Lambeth Group and Thanet sand. The section from Chambers Wharf to Abbey Mills would be constructed using a Slurry Machine as would the Greenwich connection tunnel as they are both likely to be constructed within water bearing fissured chalk.

7.2.10 The section of the 2.6m to 3m internal diameter Frogmore connection tunnel under the river is likely to be constructed using an EPBM but the section from King Georges Park to Dormay Street could use an open faced shield as it is in London Clay.

7.2.11 The remainder of the connection tunnels are shorter and are likely to be constructed with Sprayed Concrete Lining (SCL).

7.2.12 The *Code of Construction Practice Part A* (see below) directs contractors to adopt best industry practices. Notwithstanding the adoption of best practice tunnelling methods, construction of the tunnels would inevitably produce some ground movement which would generally lead to a settlement trough with the maximum settlement typically directly above the assumed tunnel centreline, reducing either side of the tunnel. The tunnel settlement and damage assessments have been calculated based upon the assumed tunnel centreline and conservative assumptions regarding the amount of movement caused at the surface. The main assumptions that make this a conservative assessment include:

a. assessing all buildings located within the settlement zone defined by the calculated 1mm contour plus an additional 5m wide buffer which is equivalent to the ‘alignment adjustment’ for the main tunnel included in the limit of deviation for the main tunnel. This means that even if the tunnel moves within the limits of deviation in the future there would be no additional damage of heritage significance.

b. adopting conservative 'volume loss' percentages that would be readily achievable by complying with the *CoCP* (see below). Volume loss is the term used to describe the empirical relationship between the tunnel excavated face area and the total volume of the settlement trough on the surface. Methods to control volume loss include increasing the face pressure on a closed face tunnel boring machine. The conservative volume loss is double what has been achieved on major tunnelling projects in the London area including Channel Tunnel Rail Link (High Speed 1).

c. assuming 'greenfield' conditions and ignoring other developments.

d. ignoring the beneficial consequences (in respect of ground movement) of tunnelling in Chalk which would result in less ground movement than calculated.

7.2.13 This conservatism means that if during the course of the detailed design and construction of the tunnel it becomes necessary to move the tunnel alignment within the limits of deviation, no materially worse impacts on listed buildings and structures would be caused.

7.2.14 Construction works and deep excavations at the following sites would induce ground movement that could potentially affect listed buildings:

a. Putney Embankment Foreshore, where the excavations for the CSO interception structure would be located adjacent to, the Grade II listed Putney Bridge's southern abutment (see Vol 3 Figure 7.4.5 in separate volume of figures);

b. Cremorne Wharf Depot, where shafts and culverts are in the vicinity of the Grade II listed Lot's Road Pumping Station (see Vol 3 Figure 7.4.6 in separate volume of figures);

c. Albert Embankment Foreshore, where the demolitions and excavations for the CSO interception structure would be adjacent to the Grade II* listed Vauxhall Bridge (see Vol 3 Figure 7.4.10 in separate volume of figures);

d. Victoria Embankment Foreshore, where demolitions and excavations for the CSO interception and drop shaft structures would be adjoining the Grade II listed Victoria Embankment river wall (see Vol 3 Figure 7.4.12 in separate volume of figures);

e. Blackfriars Bridge Foreshore, where the demolitions and excavations for the CSO interception and drop shaft structures would be adjoining the Grade II listed Victoria Embankment, adjacent to the Grade II listed Blackfriars Bridge, and in the vicinity of five listed buildings on the north side of Victoria Embankment (see Vol 3 Figure 7.4.14 in separate volume of figures);

f. Kind Edward Memorial Park, where the shafts and culverts of the CSO drop shaft would be close to the Grade II Listed Rotherhithe Tunnel Air Shaft (see Vol 3 Figure 7.4.19 in separate volume of figures); and

g. Deptford Church Street, where tunnels and shafts would be near to the boundary of the Grade I listed St Paul's Church (see Vol 3 Figure 7.4.22 in separate volume of figures).

Code of Construction Practice

7.2.15 The *Code of Construction Practice* (*CoCP*) sets out the measures and procedures which would be adopted to ensure that the heritage assets are protected from the effects of settlement. The *CoCP* is provided in Vol 1 Appendix A. It contains general requirements (Part A), and site specific requirements (Part B).

7.2.16 For each site a *Heritage management plan* would be prepared that would set out the measures to protect designated heritage assets from settlement (*CoCP Part A* Section 12.2) including monitoring, establishing limits of acceptable movement and procedures for repair to listed buildings damaged as a result of ground movement (*CoCP Part A* Section 12.3).

7.2.17 Section 13 of the *CoCP Part A* sets out the measures that would be implemented to protect existing infrastructure and buildings from ground movement, including listed buildings. There would be initial pre-condition surveys prior to the commencement of any works that have the potential to generate ground movement (*CoCP Part A* Section 13.1).

7.2.18 Where necessary protective measures would be undertaken and the installation of instrumentation and monitoring would be used to confirm that ground movement is as predicted and acceptable (*CoCP Part A* Section 13.1).

7.2.19 Section 13.2 of *CoCP Part A* requires contactors to design and carry out construction of the project in a manner that would minimise the impact on third-party infrastructure and buildings as a result of ground movement and other construction related activities. The contractors would also utilise best practice methods to reduce, control and limit ground movement, including the selection of suitable tunnelling techniques and the selection and operation of modern tunnel boring machines (TBM).

7.2.20 Where required instrumentation and monitoring would be attached to sensitive listed buildings and structures, or those where a risk of damage is predicted in such a way as to limit the adverse effects on their special architectural or historic interest, thus preserving their significance. The need for this can be minimised by establishing survey points to monitor movement of the adjacent ground and confirm this is behaving as predicted.

7.3 Assessment methodology

7.3.1 The methodology for preparing the project-wide effects assessment is described in Vol 2 Environmental assessment methodology Section 7. Engagement and methodological assumptions and limitations of specific relevance to the project-wide assessment are described below.

7.3.2 Each listed building or structure along the route has been assessed for their sensitivity to ground movement and settlement impacts using established recognised methods successfully used on other major tunnelling projects in London (Jubilee Line Extension and High Speed 1) and the UK.

7.3.3 The approach to damage assessment and mitigation is conservative and encompasses all variations of tunnel alignment within the limits of deviation (see 7.2.12).

7.3.4 Greenfield settlement contours were generated for the Thames Tideway Tunnel project based on empirical formulae to determine the predicted ground movements arising from construction accounting for both the assumed horizontal and vertical tunnel alignments and the location of the shafts. These are movements at the ground surface, calculated on the premise that the ground is a greenfield (ie, free of development) and are a conservative prediction.

7.3.5 A five metre buffer zone was added to the 1mm contour to allow for the tunnel alignment adjustment allowance within the limit of deviation and to provide a robust envelope for the potential zone of influence of the scheme. The assets within this envelope and their owners were identified. This extensive land referencing included record searches and discussions with local authorities and other statutory bodies.

7.3.6 All the known existing and proposed assets identified within the potential zone of influence of the scheme were recorded and classified in terms of asset type, such as bridge, tunnel, flood defence, utilities and buildings and whether they were listed.

7.3.7 Assessment works were undertaken to establish the predicted impact of the proposed scheme on these assets. These assessments were used to identify any potential mitigation works and also to inform any monitoring requirements.

7.3.8 Damage assessment for settlement impacts to listed buildings has been undertaken based on the model developed by Burland *et al.* (1995[2]) for the assessment of ground movement impacts to masonry buildings. The damage assessment uses geotechnical parameters to produce a model of how much the ground is likely to settle, which is measured in millimetres, the shape of the settlement trough and the maximum slope of the trough. Settlement would be greater over the tunnel and less to either side. The lines where the same degree of settlement is predicted are referred to as ‘contours’. Thus, beyond the line where 1mm of settlement is predicted (the 1mm contour), no risk of damage as a result of ground movement is predicted. The damage assessment uses a combination of geotechnical and structural information to produce a Damage Risk Category score, predicting the level of damage that the structure is at risk of being subjected to. In this case the sensitivity of each building’s heritage significance and information on the condition of the building or structure are also considered. The listed building damage assessment reports are appended to this volume as Vol 3 Appendix E.1.

7.3.9 Damage assessment for settlement to bridges, a listed tunnel and listed river walls has been assessed differently as the Burland *et al.* model (Burland, 1995)[3] developed for loadbearing masonry structures does not apply. These structures have been subject to both specific structural and heritage sensitivity and significance assessments and the resulting information used to assess damage to the heritage significance that is expected from tunnel induced movement.

7.3.10 The results of the damage assessments are utilised within this document as the basis for assessment of the route-wide impacts of the proposals on the historic environment.

7.3.11 The project-wide assessment covers all of the years of construction, as the most significant settlement is likely to take place throughout the construction period (see para. 7.1.6 above).

7.3.12 The assessment area extends along the route of the main tunnel and the portion of the connection tunnels that are not within the limits of land to be acquired or used (LLAU) of the surface work sites (Vol 4 to 27).

Engagement

7.3.13 Vol 2 documents the overall engagement which has been undertaken in preparing the *Environmental Statement*. Specific comments relevant to the project-wide assessment of effects of ground movement on the historic environment are presented in Vol 3 Table 7.3.1.

Vol 3 Table 7.3.1 Historic environment – stakeholder engagement

Organisation	Date	Comment	Response
English Heritage	September 2011 (phase one consultation); May 2012 (phase two consultation); Meetings on 30 May 2011 and 22 September 2011	Discussed and agreed assessment methodology for listed buildings.	Noted.
		Suggested that only listed buildings and scheduled monuments be assessed for damage, as is the case with other UK major tunnelling projects.	Agreed.
		Locally listed buildings do not need to be included in the project-wide assessment	Agreed.
All local planning authorities potentially affected by the proposed development	November 2011 (workshop) Presented the assessment methodology for listed buildings.	Requested clarification on the extent of assessments, such as whether they including listed viaducts and bridges.	Confirmed that listed viaducts and bridges are included in the assessment.
		Provided useful information about	Noted.

Organisation	Date	Comment	Response
		developments to and the status of listed buildings that they were familiar with.	
London Borough (LB) Lewisham		Questioned whether locally listed buildings would be included in the assessment	The project wide assessment includes statutorily designated heritage assets only. Locally listed and unlisted buildings would be protected in accordance with the *Code of Construction Practice*.
Corporation of London		Made a request for settlement contours, and also requested that if mitigation measures should affect archaeology that this should be addressed appropriately.	Settlement information has informed the assessment and in relation to listed buildings are shown in Vol 3 Appendix E1 and E2. As no grouting is proposed, ground movement mitigation would not require ground disturbance. There would therefore be no damage to archaeology. Any archaeology revealed by opening up works would be recorded in accordance with the *Overarching Archaeological Written Scheme of Investigation* (*OAWSI*), and in accordance with *CoCP*.
LB Southwark		Requested whether Scheduled Monuments would be included in the assessment.	The assessment includes scheduled monuments affected by settlement and there were found to be no effects.
English Heritage	May 2012	Expressed concern that not all of the buildings affected by at least 1mm of settlement had been inspected internally where owners were not traceable or would not respond.	Agreed to include more detail on these buildings in the damage assessment. Additional research was undertaken; these buildings are presented in more detail in the damage assessment reports (see Vol 3 Appendix E.1).
		Questioned the sensitivity scores	The methodology assesses the buildings' sensitivity to the

Organisation	Date	Comment	Response
		used for buildings on the 'Heritage at Risk' register (English Heritage, 2012)[4] and particularly sensitive buildings such as St Paul's Church in Deptford.	movements predicted and that condition and fragility of significant features and materials is considered within the assessment. Comments on the significant buildings have been addressed and their sensitivity identified and factored into the damage assessment reports (see Vol 3 Appendix E.1).
		Accepted that the approach to mitigation at Lots Road Pumping Station and Greenwich Pumping Station, where a risk of damage is predicted, would consist of repair to damage to the building after ground movement had reduced to an acceptable level following the significant ground movements, using standard conservation methods and requested that design minimised potentially adverse effects on significant elements.	This was welcomed, as it is felt that this approach would cause least damage to the significance of the building
English Heritage Section 48 publicity comments	October 2012	English Heritage noted that the historic environment has now been scoped out of the project-wide impacts of the development. English Heritage recommended that project-wide impacts are considered in the context of the Bazalgette sewer system, as this is a	A project-wide assessment of effects on the historic environment has been undertaken, as presented in this volume. The S48 publicity reported no significant effects rather than historic environment project-wide assessment being scoped out. It focuses on ground movement effects arising from tunnelling. It is considered that there are no other effects on heritage assets resulting

Organisation	Date	Comment	Response
		project-wide heritage asset which is being adapted as part of the scheme.	from the construction or operation of the tunnel that would have an additional effect to those assessed within the individual site assessments. The effects on heritage assets are localised to each site and therefore do not contribute to any project-wide effects. Cumulative effects from neighbouring sites are also assessed in the relevant site volumes, and again therefore do not constitute project-wide effects. English Heritage indicated at a meeting on 11th October 2012 that they were content with this approach. However, EH suggested that the project-wide assessment could make reference to Thames Tideway Tunnel project's contribution to the longevity of the Bazalgette legacy. This has been reflected in para. 7.1.7.

Assumptions and limitations

Assumptions

7.3.14 As stated in para.7.2.12, the damage assessments have been based on conservative assumptions on the amount of surface movement. If the tunnel alignment moves within the limits of deviation no materially worse impacts would be caused to the listed buildings or scheduled monuments within and beyond the zone within which the current assessment predicts 1mm or more of settlement, than are identified in the assessment.

Limitations

7.3.15 During the assessment of likely settlement effects to listed buildings, each building has been subject to a site inspection to determine their baseline condition, structure and heritage significance. However, for six of the listed buildings internal inspection has not been possible due to the inability to gain access. In these cases, assessment has been made on the basis of more detailed desk based research together with an external visual examination of the building. For these buildings, it has not been possible to take account of any internal alteration or condition, although the general structural form is understood.

7.3.16 For the listed bridges and viaducts, inspection has been made from publicly accessible areas of the structures and surrounding land, and where possible from the foreshore. The nature of these structures is such that their structural form can generally be understood when viewed within these limitations, as much of the structure is visible.

7.4 Baseline conditions

7.4.1 The following section sets out the baseline conditions for historic environment within the assessment area. Future baseline conditions (base case) are also described.

Current baseline

7.4.2 The following section sets out the baseline conditions for the historic environment within the settlement assessment area.

7.4.3 There are 15 listed bridges and viaducts within the area of assessment. One of these, the 1830s Greenwich Railway viaduct has been assessed in five different lengths, reflecting the bridges and lengths of viaduct between them. There is also a listed tunnel, The Brunel Thames Tunnel, and the listed river wall at Victoria Embnakment. These have been assessed using the methodology described in Section 7.3.

7.4.4 There are 31 other listed buildings in total that are assessed under project-wide effects, as being affected by at least 1mm of settlement generated by tunnelling and site construction.

7.4.5 Following the methodology for assessing the significance of heritage assets, all listed buildings and structures are deemed to have high significance.

7.4.6 The listed buildings and structures are described below. They are organised by listing grade with buildings described in each section first, and Grade II buildings are divided by local authority area. These are followed by bridges and viaducts. The listed buildings and structures assessed are shown in Vol 3 Figures 7.4.1 to 7.4.23 (see separate volume of figures).

Grade I

7.4.7 There is one Grade I listed building assessed under project-wide effects. This is St Paul’s Church, Deptford, within the LB of Lewisham (see Vol 3 Figure 7.4.22 in separate volume of figures). Built between 1713 and 1730 by Thomas Archer, St Paul’s Church is faced in ashlar Portland stone in an English Baroque style. The body of the church is raised over the crypt and is situated within a large graveyard. It has a western tower topped by a spire, and there is a semi-circular western Doric portico. The bell tower within the spire shows a roof structure of vast timbers, and retains the bell. The interior of the church, recently the subject of major funding for restoration, has Corinthian orders and very fine decorative plasterwork and painted detail, and retains pews, monuments, a timber pulpit, an organ. The building is in good condition, with some minor erosion to exterior stonework; the walls of the churchyard are in poor condition and leaning in areas. The building is of high significance due to its listing status and its interior and exterior features.

7.4.8 Tower Bridge (see Vol 3 Figure 7.4.16 in separate volume of figures) is also a Grade I listed structure. The bridge was designed by Sir John Wolfe Barry with architectural features by Sir Horace Jones, and opened in 1894. It is a bascule bridge with a suspended approach and high level footbridges between twin stone towers and cast iron balustrades. The hydraulic machinery is still used to open bridge. Tower Bridge is within two London boroughs, LB of Tower Hamlets and LB of Southwark. The bridge has high significance.

Grade II*

7.4.9 There are two Grade II* listed buildings, and five Grade II* listed bridges, and a Grade II* listed tunnel assessed within the project-wide assessment area.

7.4.10 1-6 Church Row, in the LB of Wandsworth, is a terrace of three storey townhouses dating from circa 1723, and built of brown brick with red brick dressings (see Vol 3 Figure 7.4.4 in separate volume of figures). The majority of internal features such as fireplaces and plasterwork survive; however, no access was gained to 5-6 Church Row. The condition of the buildings is variable; No.4 being is good condition, and Nos.1-3, now offices, being fair to poor with some cracking to finishes. There are ancillary buildings to the rear of the main buildings, including the former British Olympic Association's headquarters and glazed roofed boardroom. This building is of high significance.

7.4.11 All Saint's Church, also in the LB of Wandsworth, dates from 1630 and was significantly altered in the mid and late 18th century (see Vol 3 Figure 7.4.4 in separate volume of figures). To the west is a bell tower, with a semi-circular apse to the east end, and the nave having a barrel-vaulted ceiling and Doric columns running both to the roof and supporting a timber gallery to either side. Although the church has been the subject of restoration to the apse and nave, it is in poor condition, with a number of surface cracks throughout, and extensive damage to decorative elements. The building is of high significance.

7.4.12 Westminster Bridge, also Grade II*, was built 1854-1862 to the designs of Charles Barry and engineer Thomas Page (see Vol 3 Figure 7.4.11 in separate volume of figures). It is a seven span wrought and cast iron structure of 250m by 26m, supported on granite faced 'concrete' piers. Each span has 15 segmental arched girders supporting a reinforced concrete deck. The decoration is gothic, to accord with the Palace of Westminster. Foundations are of mass concrete filled caissons. The bridge was strengthened in 1997 and substantially refurbished in 2005-2007. The structure is of high significance.

7.4.13 Located in the LB of Hammersmith and Fulham, Hammersmith Bridge is an elaborate Grade II* three span suspension bridge, built in 1884 to the designs of Sir Joseph Bazalgette (see Vol 3 Figure 7.4.3 in separate volume of figures). The bridge was strengthened in 1973, and restored in 2000. The bridge is 250.5m long and 13.1m wide carrying a two-lane carriageway and flanking footways. The bridge deck is constructed of wrought iron girders and heavy timber beams with wrought-iron parapets and is suspended on mild steel chain links from two wrought-iron towers.

Piers are of Portland stone clad concrete. The bridge appears to be in good condition, structurally sound and well maintained. The bridge is of high significance.

7.4.14 Vauxhall Road Bridge is a Grade II* five span steel arched structure with granite faced concrete piers and abutments (see Vol 3 Figure 7.4.10 in separate volume of figures). It was opened in 1906 and was designed by Alexander Binnie and Maurice Fitzmaurice. Between the spans, the bridge incorporates bronze sculpture designed by Alfred Drury and Frederick Pomeroy. The bridge was altered in 1973 to accommodate an additional lane of traffic by altering the balustrades and pavements. The bridge was last refurbished in 2002. The bridge is located in the LB of Lambeth and the City of Westminster, and has a high significance.

7.4.15 Waterloo Road Bridge (see Vol 3 Figure 7.4.13 in separate volume of figures) and Albert Bridge (see Vol 3 Figure 7.4.7 in separate volume of figures) are both Grade II* listed, and are of high significance.

7.4.16 Located in the LB of Lambeth, Waterloo Road Bridge was constructed in 1939-1945, designed by Rendel, Palmer and Tritton with Sir Giles Gilbert Scott as consulting architect. The structure is of reinforced concrete with Portland stone cladding and piers of granite. Five pairs of parallel wide segmental arches rest on boat-shaped cutwaters with broached buttresses at the arch springs. The piers are of hollow construction with transverse walls to carry the superstructure. This consists of four reinforced concrete beams which are continuous over the two outer spans to provide cantilever arms for the centre section. The bridge parapet has a ribbed band in high relief and steel guard rails.

7.4.17 Albert Bridge, which is half in the Royal Borough (RB) of Kensington and Chelsea and half in the LB of Wandsworth, was constructed in 1873. It is a cable splayed bridge, partly suspended and partly cantilevered and supported by two turreted arches made of cast iron from which chains of flat wrought iron radiate. The centre of the span is supported by a modern steel pier erected circa 1972. The bridge underwent major renovation in 2010-2011, and is in good condition.

7.4.18 Brunel's Thames Tunnel (see Vol 3 Figure 7.4.18 in separate volume of figures), currently the London Overground tunnel, which is within both LB Tower Hamlets and LB Southwark, was built in 1825-1843 by Marc Isambard Brunel, assisted by Isambard Kingdom Brunel. It was, constructed using a revolutionary tunnelling shield patented in 1818 by Marc Isambard Brunel. The structure consists of two parallel horseshoe section brick vaulted tunnels, joined by cross arches at intervals. The brickwork is bonded in Roman Cement, to provide some waterproofing. The inner face of the tunnels is lined with clay tiles covered in stucco. The stucco is scored in imitation of ashlar stonework. It was the first tunnel beneath the Thames. The tunnel is of high significance.

Grade II

7.4.19 There are 29 Grade II listed buildings, within the project-wide assessment area, all of which have high significance and one of which (the Victoria

Embankment) appears in two local authority areas, on two sites. These are described in paras. 7.4.20 to 7.4.47 below.

London Borough of Hounslow

7.4.20 60-62 Bath Road are a pair of brick houses, dating from the late 19th century, which were listed as part of a wider group relating to the Bedford Park Estate (see Vol 3 Figure 7.4.1 in separate volume of figures). At the time of inspection the interior of 62 Bath Road was accessible, although the interior of No. 60 was not. The pair are generally in good condition, with some minor deterioration of the brickwork to the front facades, and evidence of some minor differential movement in the join between the original and modern fabric of No. 60. The interior of 60 Bath Road has been modernised and altered to the rear of the property.

7.4.21 Swan House is a three storey brick built house dating from the late 18th century (see Vol 3 Figure 7.4.2 in separate volume of figures). It is part of a terrace and shares construction with Cedar House. No internal inspection has been carried out of Swan House. The exterior of the building (front façade) appears to be in good condition. Cedar House, attached to Swan House but separately listed, is a three storey brown brick building dating from the late 18th century. Externally the building is in good condition. Internally, no original features remain, though the current owner has re-instated Georgian style decorative features, stairs and shutters. There is an extension to the rear (north) of the building. There are no visible structural defects, although there is some localised crazing to interior finishes.

Royal Borough of Kensington and Chelsea

7.4.22 Lots Road Pumping Station dates from 1904 with further alterations occurring in the early 1930s and late 1950s/1960s (see Vol Figure 7.4.6 in separate volume of figures). The principal elevation of the pumping station is its frontage onto Lots Road. Its Lots Road and gable end facades are faced in red brick divided into arched bays and with brown glazed decorative brickwork. There is limited architectural interest to the rear elevation, which is plainer than the front elevation and is made up of plain yellow stock bricks, with few openings, and which is screened by the presence of the existing works depot. Internally there are localised areas of glazed tiling to dado height, and fixtures and fitting of interest relating to the use of the building.

London Borough of Wandsworth

7.4.23 7-9 Church Row is a three storey, four bay brick house with sash windows, built in the early 18th century (see Vol 3 Figure 7.4.4 in separate volume of figures). To the rear of the building is a two storey range of former Victorian cottages, now studios, set at right angles to the main building. The building is in poor condition, and being slowly improved and repaired by the current tenants. There are signs of modest historic movement, internal alteration, and lack of maintenance.

7.4.24 Also in Wandsworth, eighteenth century Wentworth House is a two storey, five bay building plus a side extension of one bay (see Vol Figure 7.4.4 in separate volume of figures). It is constructed of brick, with a good quality timber door case with a decorative hood to the main front elevation. There are later rear extensions and workshops to the north. The house is currently empty, having been used as offices, and is showing signs of lack of maintenance, water ingress and vegetation growth. Overall it is in poor condition. The walls, gate and gate piers, also part of the listing, are in good condition.

City of Westminster

7.4.25 There is a single Grade II listed building affected by ground movement in Westminster. The Victoria Embankment was built by the Metropolitan Board of Works to the designs of Sir Joseph Bazalgette in 1864-70. The river wall is granite faed. Its upper part and parapet have a heavy segmental rolled coping with regularly spaced dies surmounted by the ornately designed lamp standards, with lions head mooring rings.

City of London

7.4.26 There are six Grade II listed buildings within the City of London (refer to Vol 3 Figure 7.4.14 in separate volume of figures). Dating from 1889, Hamilton House is a commercial building faced in Portland stone. The façade is decorated with foliate detail. Internally, some decorative plasterwork and two cantilevered stairs remain. The basement also retains some decorated timber panelling. The building is occupied and in good condition.

7.4.27 Telephone House is a four storey commercial building dating from 1900, with a stone façade carrying decorated sculpture. Internally, the building retains some plasterwork, a cantilevered stair, and tiled ‘Telephone Network’ inscribed fireplaces. The building is in good condition and has been sensitively modernised for current office use.

7.4.28 Sion House is a Tudor Gothic style brick building with stone dressings, dating from 1886, with a later brick extension to the south built around 1965. External stone details include carved grotesques and armorial devices. Internally the building retains many features including a high quality stone cantilevered stair, plasterwork and stained glass. The double-height central former library space is galleried and has a hammerbeam ceiling. The building is now occupied for office use, and is in good condition; however, externally stonework shows areas of replacement and localised spalling.

7.4.29 Dating from 1893-1894, 9 Carmelite Street is a brick building with stone dressings, in a Tudor Gothic style. The decorative stonework has much in common with that of Sion House. Internally, the building now has office use but retains plaster and timber details, including a very decorative plaster ceiling to the upper section of the former double height library (now two spaces). There is also a stone cantilevered stair, which now has additional support in the form of iron bracing. The building is in good condition.

7.4.30 Carmelite House dates from the late 19th century. The current composition of the building is one stair tower to the north-east, and the northern and eastern elevations of the building, which are of brick with stone dressings. Behind these facades is a modern office block constructed in the late 20th century. The stair tower interior is decorated with neo-classical frescoes, and holds an Otis lift dating from the early 20th century. The facades and stair tower of the building are in good condition, and the office space within is partially used and currently undergoing refurbishment.

7.4.31 The listed Victoria Embankment's river wall runs along the western part of the main site at Blakfriars Bridge Foreshore. It was built by the Metropolitan Board of Works to the designs of Sir Joseph Bazalgette in 1864-70. The river wall is granite faed. Its upper part and parapet have a heavy segmental rolled coping with regularly spaced dies surmounted by the ornately designed lamp standards, with lions head mooring rings.

London Borough of Southwark

7.4.32 There are three Grade II listed buildings within the LB of Southwark (see Vol 3 Figure 7.4.17 in separate volume of figures). Corbetts Wharf is a former industrial dockside building, now converted to flats. Dating from 1860-1870, it is of brick to all elevations. Internally, the building has only been partially inspected; the ground floor flats have cast iron columns, timber floors and beams, and the top floor flats retain an open timber roof structure. There are signs of movement to the external facades, with cracks to the south and west elevations, and the building is generally in poor condition.

7.4.33 Chambers Wharf is a former warehouse dating from 1865-1870, built of stock brick in five storeys, now with modern roof additions. The building is now converted to flats, and has been entirely modernised to the internal public areas including new structure and stairs; no access has been available to the flats themselves. The building is in good condition, although there is a slight historic lean to the southern elevation.

7.4.34 A former granary, dating from 1866, 33 Bermondsey Wall East is a five storey building constructed of brick, with modern roof additions. The building has been converted to flats, and internal public areas show modern structure and finishes. No access has been available to the flats. Internally the building is in good condition; externally, there is evidence of historic movement, with a lean to the southern elevation, and tie-plates visible to the northern and southern elevations. However, no cracking is evident.

London Borough of Tower Hamlets

7.4.35 There are 13 Grade II listed buildings located within the LB of Tower Hamlets. Free Trade Wharf dates from 1796, and consists of two former warehouses with a courtyard between, now converted to apartments (see Vol 3 Figure 7.4.19 in separate volume of figures). The elevations are of brick, in some areas patched and replaced. The ground floors of the buildings contain garages and to the west a swimming pool. The general condition of the building is good, although with localised areas of spalling (crumbling of the face of bricks or stone blocks) and erosion to brickwork. No access has been available into the interior.

7.4.36 The Prospect of Whitby Public House dates at its earliest from 1520, although the building comprises many phases of alteration and extension, and a 19th century main façade (see Vol 3 Figure 7.4.19 in separate volume of figures). Elevations are of brick, with the rear elevation resting upon the river wall and incorporating a balcony structure resting on the foreshore. The interior has largely been altered with modern ‘historic’ fittings, although some panelling and plasterwork remains to the first floor. The condition of the building is largely good; however there is evidence of historic movement to the north where there is a slight lean and skew. The balcony structure has been renewed.

7.4.37 Now also a public house, Customs House dates from 1905-1910 and was built for British Waterways (see Vol 3 Figure 7.4.20 in separate volume of figures). It is constructed of red brick with stucco and stone dressings, and has two storeys. Internally, the building has been subject to modern refurbishment, with few historic features remaining aside from fireplaces. The building is in fair condition, with minor cracking externally around openings, and a resultant erosion of brickwork in these areas.

7.4.38 The British Sailor’s Society, a 19th century training establishment, has now been converted into residential accommodation (see Vol 3 Figure 7.4.20 in separate volume of figures). The elevations are of brick. No access has been available to this property; however documentary evidence mentions a Victorian swimming pool in the basement. Externally, the building appears to be well maintained and is in good condition.

7.4.39 Dating from 1879, Limehouse Town Hall is a purpose built public building, of brick with stone dressings and a grand columned entrance to Commercial Road (see Vol 3 Figure 7.4.20 in separate volume of figures). Internally, the building retains historic features such as a cantilevered stair, plasterwork, and a double height public hall with ornate decorative plaster. The building is ‘At Risk’, and in very poor condition, with failures at roof level leading to water ingress, localised cracking, and damage to plaster and decorative schemes. A Trust now manages the building and is progressing repairs.

7.4.40 Constructed of yellow brick and Portland stone, Limehouse Library was purpose built in 1900 (see Vol 3 Figure 7.4.20 in separate volume of figures). Behind the main building is a long rear section, of later construction. The interior retains historic features including a large fresco within the main library, timber stairs, and glazed rooflights. The building is no longer in use, and is ‘At Risk’; its condition is very poor, with extensive water ingress and vegetation causing damage to interior features, and cracking to the exterior, particularly to the rear of the building.

7.4.41 The wall to St Anne’s Rectory, listed in its own right, has two distinct phases of construction, with older brick (possibly dating from the 16^{th} century) at its eastern end, and 19^{th} century brick to its western end (see Vol 3 Figure 7.4.20 in separate volume of figures). At the eastern end the wall is approximately two metres high, and has regular brick caps; the wall is thicker at its base than its top. The older section has been repointed in cement mortar, causing some deterioration of the brick. The western end, though similar in construction, lacks the brick caps, and has lime mortar which has deteriorated. There are brick piers at either end of the wall, with the eastern pier having a brick cap, and the western pier a concrete cap. There are a number of existing cracks through the brick to the older section of wall.

7.4.42 Grade II listed Limehouse Accumulator Tower is situated to the south of the London and Greenwich Railway viaduct, and is described in the list description as a former railway look out tower (see Vol 3 Figure 7.4.20 in separate volume of figures). In the past, the building housed accumulator machinery associated with the workings of the canals of Limehouse; it is octagonal in plan, constructed of brick and with a tall brick chimney to its north side. The building now contains modern stairs and has a viewing platform behind its parapet.

7.4.43 The Rotherhithe Tunnel Air Shaft, within King Edward's Memorial Park, is a single storey circular red brick building with Portland stone dressings, with a slate covered roof with a central brick and stone cupola (see Vol 3 Figure 7.4.19 in separate volume of figures). The entrance is to the south, and incorporates two openings within one bay, with stone surrounds. Each other bay has a double opening, again with stone surrounds; these openings contain wrought iron tracery incorporating the letters 'LCC'. The shaft itself contains stairs and hoists associated with the use of the Rotherhithe Tunnel.

7.4.44 Dowgate Wharf dates from the early 19th century, and is a former warehouse, now flats, constructed of brick with two storeys. No inspection has been possible of this building; however it is believed to be in good condition.

7.4.45 777 to 783 Commercial Road comprises an office block at 777 dating from 1893-94, and a slightly later range of warehouses including a sail makers loft to the western range (see Vol 3 Figure 7.4.20 in separate volume of figures). As a whole, the building is of brick, with offices of three storeys and warehousing of two storeys. There remains some historic machinery in the galleried eastern warehouse ranges. The building is in very poor condition, and is included in the 'Heritage at Risk' register. Much of the roof materials have failed, although a temporary roof covering has been placed over the sail makers loft. This loft also has temporary propping. The rest of the building has many cracks and localised areas of damage, and is deteriorating.

7.4.46 Metropolitan Wharf comprises four warehouses built in 1870-1880; the blocks are named 'A', 'B & C', and 'D' within their separate listing designations (see Vol 3 Figure 7.4.19 in separate volume of figures). All blocks are constructed of brick, with internal cast iron and timber columns, timber roof structure and floors. The buildings are now in office use having been extensively refurbished, and are in good condition.

London Borough of Lewisham

7.4.47 Located in the LB of Lewisham, and built in 1903 by the LCC Fire Station Division, Deptford Fire Station (see Vol 3 Figure 7.4.22 in separate volume of figures) is a brick building with a Queen Anne style front façade, and a utilitarian rear façade of central stair and iron balconies for access to the administrative and residential accommodation. There is an engine room at ground floor level. The building is still in use by the fire department, and is generally in good condition, although the upper floors have been neglected and show some areas of damp. However, these spaces are in the process of repair and redecoration.

7.4.48 227 Deptford High Street is also in the LB of Lewisham (see Vol 3 Figure 7.4.22 in separate volume of figures). Dating from 1791-92, this former bakehouse and shop is part of a high street terrace, and is built of brick. No access has been gained to this building. The building is 'At Risk', and understood to be in very poor condition, with a number of alterations and removals of heritage features. The bakehouse is said by the local authority to have been destroyed.

Royal Borough of Greenwich

7.4.49 Greenwich Pumping Station is located in the Royal Borough of Greenwich (see Vol 3 Figure 7.4.21 in separate volume of figures). The pair of beam engine houses with linking boiler house at Greenwich Sewage Pumping Station were designed by Sir Joseph Bazalgette and opened in 1865. An extension to the western beam engine house was added in 1905. The range of buildings are of brick with stone dressings, with the west engine house retaining machinery relating to its use. The eastern beam engine house has been stripped and is now unused. The condition of the site is fair, although the east beam engine house shows some minor damage to brickwork and vegetation growth. There are a number of ancillary buildings across the site, generally in poor condition when unused, and well maintained where still in use.

Bridges and viaducts

7.4.50 There are 13 Grade II listed bridges and stretches of viaduct within the project-wide assessment area, all of **high** significance. These form part of nine listed buildings, as the London and Greenwich railway viaduct has been assessed as five separate structures. They are set out below.

7.4.51 The present Putney Road Bridge was built in 1882-1886 to the designs of Sir Joseph Bazalgette (see Vol 3 Figure 7.4.5 in separate volume of figures). The 149m long bridge has five spans and is of masonry construction, with channelled stone cladding. The bridge was widened by approximately 9.1m on its east side in 1933. The mass concrete deck is supported on closely spaced longitudinal brick spandrel walls supported on the bridge arches. The bridge is in the LB of Hammersmith and Fulham.

7.4.52 Battersea Road Bridge, half in RB Kensington and Chelsea with the southern part in the LB of Wandsworth, was built in 1886 to 1890 by John Mowlem & Co. to the designs of Sir Joseph Bazalgette (see Vol 3 Figure 7.4.7 in separate volume of figures). The bridge comprises a 5-span wrought and cast iron structure with a total length of 221.5m supported on granite piers. It bears ornate decorative design. Strengthening works were undertaken to the bridge in 1992-93, and the bridge is generally in good condition, although there is some erosion of the decorative paintwork, and vegetation growth to brick piers. Chelsea Bridge, in the RB of Kensington and Chelsea, is a three span steel suspension bridge carried on granite faced reinforced concrete piers and abutments (see Vol 3 Figure 7.4.8 in separate volume of figures). It is historically notable as the UK's first self-stabilising (self-anchored) suspension bridge, built in 1935-7. The bridge remains much in its historic form, and is in good condition aside from minor weathering to the decorative coatings and minor cracking to the decorative balustrade. Chelsea River Bridge, listed as Cremorne Bridge, was named after the Cremorne pleasure gardens which formerly stood on the site now occupied by the Lots Road Power Station (see Vol 3 Figure 7.4.8 in separate volume of figures). The Cremorne Bridge was built in 1863 to the designs of William Baker, Chief Engineer of the London and North West Railway Company (LNWR), and his counterpart T H Bertram of the Great Western Railway (GWR). It is a five-span wrought-iron arch bridge, which is flanked at either end by six-span brick arch viaducts on the east and west shores of the river. The spans are carried on riveted wrought-iron arched ribs arranged in pairs which are joined by lattice spandrel members to the deck girders. There are three pairs of ribs to each span, with the inner ribs cross braced. Some of this cross bracing is later 20th century strengthening work. The bridge is of particular historic significance as it was one of the earliest railway bridges to cross the Thames, and among the earliest surviving examples. The bridge is in fair condition, although surface corrosion and some vegetation growth is in evidence.

7.4.53 Lambeth Road Bridge (see Vol 3 Figure 7.4.9 in separate volume of figures) was built 1929-1932 to the designs of Sir George Humphreys, with Sir Reginald Blomfield and George Topham Forrest as consulting architects and was erected by Dorman Long & Co. It is a five span steel arch structure carried on granite faced reinforced concrete piers and abutments. The bridge has symbolic ornamentation which celebrates the former London County Council and the reign of George V. The bridge was strengthened in 1996, without altering its outward appearance. The bridge is in the LB of Lambeth.

7.4.54 Blackfriars Road Bridge was built in 1869, probably by Joseph or James Cubitt (see Vol 3 Figure 7.4.14 in separate volume of figures). The five span bridge has four polychromatic granite clad piers with gothic decoration. The end engaged columns have Portland stone capitals. Each span has 12 shallow arched wrought iron plate girders. The cast iron balustrades have varied gothic balusters. The bridge was widened by 11m in 1909. The bridge is within the City of London.

7.4.55 Southwark Road Bridge was built in 1913-1921 by Sir William Arrol & Co. to the designs of Engineers Mott Hay and Anderson and architect Sir Ernest George RA (see Vol 3 Figure 7.4.15 in separate volume of figures). Its five spans align with those of Blackfriars Bridge. The 216m long structure is of steel and is supported on granite faced piers and abutments. Each span has seven 'I' section fabricated ribs, which support spandrel columns, which in turn carry longitudinal I section members over which transverse girders support a steel buckle plate deck which sits on steel beams. The abutments are vaulted to allow the passage of pedestrians. The bridge is ornately decorated. The upper section of the concrete deck beneath the carriageway was replaced with light concrete infill and Trief kerbs were introduced in 2005. The bridge was refurbished in 2009-2010.

7.4.56 The DLR Viaduct on Island Row, in the LB Tower Hamlets, was designed by Robert Stephenson, was originally built as part of the London and Blackwall railway and was opened in 1840 (see Vol 3 Figure 7.4.20 in separate volume of figures). The viaduct is brick built, with shallow arches and a moulded sandstone string course beneath its low parapet. For most of the parapet's height it consists of a cast iron balustrade. The parapet is in good condition.

7.4.57 Sun Wharf Viaduct, in the LB of Lewisham (see Vol 3 Figure 7.4.21 in separate volume of figures), formerly formed part of the London and Greenwich Railway, which opened in 1836. The viaduct is formed of 15 regular brick arches, with a later brick parapet to the upper level on the north side, and a metal handrail to the south side. The viaduct is in fair condition and in good structural repair; however there is some vegetation growth and areas of damaged brickwork or failed pointing.

7.4.58 Mechanic's Path Viaduct, also in Lewisham (see Vol 3 Figure 7.4.21 in separate volume of figures), formed part of the London and Greenwich Railway, which opened in 1836. The viaduct is formed of 30 regular brick arches, with the brickwork continuing upwards to form a parapet to the north side, and a reinforced capping beam and metal handrail on the south side. Underneath the arches, light industrial units have been formed. The viaduct was refurbished between 2000 and 2003, and is in good condition.

7.4.59 Hart's Wharf Viaduct, again in Lewisham (see Vol 3 Figure 7.4.21 in separate volume of figures), formed part of the London and Greenwich Railway, which opened in 1836. The viaduct is formed of 15 regular brick arches, with brick parapets above. The viaduct is in fair condition, and is structurally sound. However, there is evidence of vegetation ingress and poorly repaired or damaged brickwork.

7.4.60 Browne House and Farrar House Viaduct formed part of the London and Greenwich Railway (see Vol 3 Figure 7.4.21 in separate volume of figures), which opened in 1836. The viaduct is formed of 17 regular brick arches, with a brick parapet above to the north side, and a metal handrail to the south. The viaduct is in fair condition, with some vegetation growth and damage to brickwork, and evidence of damp within the arches. The viaduct is within the LB of Lewisham.

7.4.61 Deptford Creek Lifting Bridge (see Vol 3 Figure 7.4.21 in separate volume of figures) was initially built by 1838 to the design of Engineer Col. Landmann. The present bridge, opened in 1963, was designed by AH Cantrell, Chief Civil Engineer of British Rail Southern Region and was built be Sir William Arrol & Co. It has two spans with a central pier. The east span is a vertical lifting bridge and the west span in a brick arch. The earlier bridges had a similar configuration. The 1963 bridge saw the replacement of the opening span and works to the abutments, central pier and cutwaters. The central sandstone pier dates to 1838. The lifting bridge was welded shut, the mechanism disconnected and counterweights removed in the late 1970s. The bridge is listed as a curtilage structure of the adjoining viaduct. An English Heritage report concluded in 2012 that the bridge does not qualify for listing in its own right, as it lacks architectural or historic interest. It has been recommended for inclusion in the LB of Lewisham's local list.

7.4.62 Twelve Trees Crescent Road Bridge (see Vol 3 Figure 7.4.23 in separate volume of figures) was built in 1872 for the Imperial Gas Light and Coke Company to the designs of Peter Barlow to span Bow Creek and the Lea Navigation, to provide access to Bromley-by-Bow Gasworks. It is built in wrought iron and cast iron. It has two spans with a central brick pier. The bridge was strengthened in the 1990s when a new deck was installed. There is a tunnel through the east abutment. The bridge is within the LB of Newham.

Fragile and sensitive Grade II listed buildings

7.4.63 Of the buildings described above, four are on the English Heritage 'Heritage at Risk' register (English Heritage, 2012)[5]. These are 777-783 Commercial Road, Limehouse Town Hall, Limehouse District Library (all in the LB of Tower Hamlets), and 227 Deptford High Street (LB of Lewisham). These buildings are of particular concern to English Heritage due to their disuse and poor condition; the condition of these buildings is also likely to make them more vulnerable to significant ground movement.

7.4.64 Further buildings discussed above, within the assessment area, have been assessed as being in 'poor condition'; these are 7-9 Church Row, and Corbetts Wharf. In these cases, the condition of the buildings presents some vulnerability of heritage features or finishes in the face of significant settlement.

7.4.65 St Paul's Church is of particularly high heritage significance; this significance is fragile, as some its most decorative features have little tolerance to movement and, if damaged, would be difficult to repair. It could be vulnerable to significant settlement, although none is predicted from the proposals.

7.4.66 The East Beam Engine House at Greenwich Pumping Station is not currently used, and is in poor condition, although it is not on the English Heritage 'Buildings at Risk' Register.

Construction base case

7.4.67 The base case includes other projects that may generate ground movement that would be built by the time of the proposed works and would change the future baseline. The development schedules setting out the schemes to be included in the construction base case (see Vol 3 Appendix A.1 and Vols 4 to 27 Appendix N) has identified three such schemes at a project wide level. These include Crossrail, Thameslink and the post London Olympics legacy development.

7.4.68 The Crossrail tunnels would be completed part way through the proposed construction period for the main tunnel. The Crossrail scheme tunnel would cross the proposed route of the Thames Tideway Tunnel project in Limehouse in LB Tower Hamlets. Both of the Crossrail running tunnels pass beneath the Grade II Listed DLR viaduct on Island Row. At this point the main tunnel would be considerably deeper than the Crossrail Tunnels.

There is a risk that the Crossrail tunnel would cause minor adverse effects to the listed viaduct. This would slightly alter the baseline condition of the viaduct. This has been taken into consideration within the construction phase assessment.

7.4.69 The Thameslink project includes some works close to the route of the main tunnel. The most relevant of these include improvements to both London Bridge Station and to City Thameslink station, situated to the north east of Blackfriars. However, the ground movement generated by the two schemes would not affect the same heritage assets, as the areas affected by settlement produced by the two projects are separate and encompass different heritage assets.

7.4.70 The London Olympics legacy works involve major remodelling around the Olympic Park in Stratford. The Thames Tideway Tunnel project tunnelling works would not cause settlement damage in the same areas and thus to the same heritage assets as the Olympic legacy scheme.

7.4.71 At a site specific level, in the area of Lots Road Pumping Station (Cremorne Wharf Depot), excavation of basements and piles during the Lots Road Power Station development would cause ground movement. Whilst no settlement contours were available to inform the assessment, it is predicted that ground movement would be minimal in the area of the Pumping Station, being greater at the source of the Power Station excavations and dissipating beyond the boundary of the Power Station site. Therefore it is not predicted that the Lots Road Power Station development would cause significant movement damage to Lots Road Pumping Station and would not change the baseline for assessment of ground movement at Cremorne Wharf.

7.4.72 Although there may be ground movement generated by the opening up of vaults beneath Putney Road Bridge during the construction of the development at 2 Putney High Street, damage from this is likely to be repaired by the developer, and would not effect the significance of the bridge. Therefore the baseline for assessment of the bridge remains unchanged.

7.4.73 Only Crossrail would alter the baseline in relation to the heritage assets affected by the Thames Tideway Tunnel project proposals, except for the Grade II listed DLR viaduct on Island Row where there maybe some additional cracking to the structure, the construction base case remains as identified in 7.4.2 to 7.4.66 above.

7.5 Construction effects assessment

7.5.1 The construction effects of ground movement on the historic environment are assessed with relevance to the period during which the effects generated from ground movement are at their peak, which is during construction of the tunnels. Although settlement and its effects are likely to be greatest during and immediately after tunnelling works in the vicinity of each particular receptor, settlement has the potential to continue beyond the construction phase, although over time the rate and degree of settlement reduces gradually. As construction activities produce the settlement and the most significant settlement is likely to have occurred by the time the tunnel is operational, the construction assessment spans the entire construction phase.

7.5.2 The effects are assessed against the findings of the Damage assessment and detailed bridge assessment reports (see Vol 3 Appendix E.1, Vol 3 Appendix E.2 and Vol 3 Appendix E.3), which detail the key significance of each listed building or structure, their vulnerabilities, and the predicted settlement and damage risk that is likely for the building or structure.

7.5.3 Vol 3 Table 7.5.1 sets out the impacts of settlement generated by the construction works upon the sensitive receptors within the assessment area, the significance of this impact to the receptor. The table sets out the listed buildings first, by borough, from west to east. The listed bridges and viaducts are then also set out from west to east.

Vol 3 Table 7.5.1 Historic environment – construction effects assessment

Name / Significance	Description of effect	Magnitude of change	Significance of effect
LB Hounslow			
60-62 Bath Road (High significance)	Settlement would be between 5mm in the east, to 1mm in the west. The damage assessment identifies the damage risk to be negligible, with the possibility of hairline cracks of a typical maximum width of 0.1mm.	Negligible	Minor adverse
Swan House (High significance	The peripheral curtilage of this building would experience a settlement of 1mm. The damage assessment identifies the damage risk to be negligible, with the possibility of hairline cracks of a typical maximum width of 0.1mm.	Negligible	Minor adverse
Cedar House (High significance)	Settlement of between 1mm and 2mm is predicted. The damage assessment identifies the damage risk to be negligible, with the possibility of hairline cracks of a typical maximum width of 0.1mm.	Negligible	Minor adverse
LB Kensington and Chelsea			
Lots Road Pumping Station (High Significance	Towards the rear of the building a maximum of 15mm of settlement is predicted, reducing to 1mm of settlement at the front, and more significant and sensitive part of the building. In the area of greatest settlement the damage assessment identifies the risk of cracks of up to 10mm due to settlement, concentrated on existing joints within the walls and where the foundations differ.	Low	Moderate adverse
LB Wandsworth			
7-9 Church Row (High significance)	Settlement between 1mm and 6mm is predicted. It could impact upon the structural and heritage significance of the west side of the building. Although the damage assessment identifies the damage risk to be negligible, with the possibility of negligible hairline cracks of a typical maximum width of 0.1mm, they	Low	Minor adverse

Name / Significance	Description of effect	Magnitude of change	Significance of effect
	would be concentrated on the façade of the building.		
1-6 Church Row (High significance)	Settlement between 1mm and 10mm at its west side is predicted. This could impact upon the structural and heritage significance of this building. Although the damage assessment identifies the damage risk to be negligible, with the possibility of hairline cracks of a typical maximum width of 0.1mm, they would be concentrated on the façade of the building.	Low	Minor adverse
Church of All Saints (High significance)	Settlement of between 1mm and 2mm at its east end is predicted. Although the building is of high significance and in poor condition, the damage assessment identifies the damage risk to be negligible, with the possibility hairline cracks of a typical maximum width of 0.1mm.	Negligible	Minor adverse
Wentworth House (High significance)	This building would experience settlement of between 1mm and 6mm across its structure. The damage assessment identifies the damage risk to be negligible, with the possibility of hairline cracks of a typical maximum width of 0.1mm.	Negligible	Minor adverse
City of Westminster			
Victoria Embankment (High Signifiance)	The river wall would be be subject to a maximum vertical settlement of 4mm. Damage assessment identifies that this would result in a potential for a negligible damage risk, with the potential for hairline cracks of a typical maximum width of 0.1mm.	Very low	Minor adverse
City of London			
Hamilton House (High significance)	The peripheral curtilage of this building would experience a settlement of 1mm. The building damage assessment identifies the damage risk to be negligible, with the possibility of hairline cracks of a typical maximum width of 0.1mm.	Negligible	Minor adverse
Telephone	The southern tip of this building would experience a settlement of 1mm. The	Negligible	Minor adverse

Name / Significance	Description of effect	Magnitude of change	Significance of effect
House (High significance)	building damage assessment identifies the damage risk to be negligible, with the possibility of hairline cracks of a typical maximum width of 0.1mm.		
Sion House (High significance)	The southern elevation of this building would experience a settlement of 1mm. The building damage assessment identifies the damage risk to be negligible, with the possibility of hairline cracks of a typical maximum width of 0.1mm..	Negligible	Minor adverse
9 Carmelite Street (High significance)	The southern elevation of this building would experience a settlement of between 1mm and 2mm. The building damage assessment identifies the damage risk to be negligible, with the possibility of hairline cracks of a typical maximum width of 0.1mm.	Negligible	Minor adverse
Carmelite House (High significance)	The southern (modern) elevation of this building would experience a settlement of between 1mm and 2mm. The building damage assessment identifies the damage risk to be negligible, with the possibility of hairline cracks of a typical maximum width of 0.1mm.	Negligible	Minor adverse
Victoria Embankment (High Signifiance)	The river wall would be be subject to a maximum vertical settlement of 88mm. Damage assessment identifies that this would result in a potential for a slight damage risk, with the potential for cracks of a typical maximum width of 5mm.	Medium	Moderate adverse
LB Southwark			
Corbett's Wharf (High significance)	Settlement of between 1mm and 3mm is predicted across its structure. Taking into account the condition of the building, the damage assessment identifies the damage risk to be negligible, with the possibility of hairline cracks of a typical maximum width of 0.1mm.	Negligible	Minor adverse
Chambers Wharf (High significance	Settlement of between 1mm and 5mm is predicted across its structure. The damage assessment identifies the damage risk to be negligible, with the possibility of hairline cracks of a typical maximum width of 0.1mm.	Negligible	Minor adverse

Name / Significance	Description of effect	Magnitude of change	Significance of effect
33 Bermondsey Wall East – (High significance)	Settlement of between 1mm and 3mm is predicted across its structure. The damage assessment identifies the damage risk to be negligible, with the possibility of hairline cracks of a typical maximum width of 0.1mm.	Negligible	Minor adverse
LB Tower Hamlets			
Free Trade Wharf (High significance)	Settlement of between 1mm and 3mm is predicted at the building's southern end. The damage assessment identifies the damage risk to be negligible, with the possibility of hairline cracks of a typical maximum width of 0.1mm.	Negligible	Minor adverse
Prospect of Whitby Public House (High significance)	Settlement of between 2mm and 6mm is predicted across its structure, with the greater settlement occurring at its rear. The damage assessment identifies the damage risk to be negligible, with the possibility hairline cracks of a typical maximum width of 0.1mm.	Negligible	Minor adverse
British Waterways Custom House (High significance)	Settlement of between 2mm and 5mm is predicted across its structure. The damage assessment identifies the damage risk to be negligible, with the possibility of hairline cracks of a typical maximum width of 0.1mm.	Negligible	Minor adverse
British Sailors Society (High significance)	Settlement of between 1mm and 4mm is predicted across its structure. The damage assessment identifies the damage risk to be negligible, with the possibility of hairline cracks of a typical maximum width of 0.1mm.	Negligible	Minor adverse
Limehouse Town Hall	Settlement of between 1mm and 4mm is predicted across its structure. Although the building is in poor condition, the damage assessment identifies the damage	Negligible	Minor adverse

Name / Significance	Description of effect	Magnitude of change	Significance of effect
(High significance)	risk to be negligible, with the possibility of hairline cracks of a typical maximum width of 0.1mm.		
Limehouse District Library (High significance)	Settlement of between 3mm and 10mm is predicted across its structure, with the greatest settlement occurring directly above the tunnel. Due to the condition of the building, and the resulting fragile heritage features, there may be an impact upon the heritage significance even though the damage assessment report (see Vol 3 Appendix E.1) identifies the risk damage to be negligible, with the possibility of cracks typically up to 0.1mm wide.	Low	Minor adverse
Dowgate Wharf (High significance)	The peripheral curtilage of this building is predicted to experience 1mm of settlement. The damage assessment identifies the damage risk to be negligible, with the possibility of the impact of hairline cracks of a typical maximum width of 0.1mm.	Negligible	Minor adverse
777-783 Commercial Road (High significance)	Settlement of between 1mm and 8mm is predicted across its structure. Although the damage assessment has identified the damage risk category as negligible, with the possibility of typical cracking of up to 0.1mm, the very poor condition of this building may be worsened by significant ground movement.	Low	Minor adverse
Block A, Metropolitan Wharf – (High significance)	Settlement of between 1mm and 2mm is predicted at its southern end. The damage assessment has identified the damage risk to be negligible, with the possibility of hairline cracks of a typical maximum width of 0.1mm.	Negligible	Minor adverse
Block B&C, Metropolitan Wharf – (High significance)	Settlement of between 1mm and 2mm is predicted at its southern end. The damage assessment identifies the damage risk to be negligible, with the possibility hairline cracks of a typical maximum width of 0.1mm.	Negligible	Minor adverse
Block D, Metropolitan	The southern edge of this building would experience 1mm of settlement. The damage assessment identifies the damage risk to be negligible, with the	Negligible	Minor adverse

Name / Significance	Description of effect	Magnitude of change	Significance of effect
Wharf – (High significance)	possibility hairline cracks of a typical maximum width of 0.1mm.		
Rotherhithe Tunnel Air Shaft – (High significance)	The maximum settlement predicted is 12mm at the eastern edge of the building, decreasing to 0mm on the western side. The damage risk associated with this movement is assessed to be negligible, typically causing cracking up to 0.1mm in the area of greatest movement, and at points of existing damage. Because of the form of the air shaft there may be a risk of differential heave to the building	Low	Minor adverse
Wall to St Anne's House – (High significance)	The tunnel alignment runs beneath the centre of the wall, at the point of the junction between older and newer brickwork. The damage assessment identifies the risk of damage to be negligible, with the possibility of hairline cracks up to 0.1mm, concentrated at this junction.	Negligible	Minor adverse
Limehouse Accumulator Tower – (High significance)	Settlement of between 1mm and 3mm is predicted, with the damage assessment identifying risk of negligible damage. There is a possibility of hairline cracking of up to 0.1mm.	Negligible	Minor adverse
LB Lewisham			
Deptford Fire Station – (High significance)	Settlement of between 1mm and 5mm is predicted, with the greatest settlement at its eastern edge. The damage assessment identifies the damage risk to be negligible, with the possibility of hairline cracks of a typical maximum width of 0.1mm.	Negligible	Minor adverse
227 Deptford High Street – (High significance)	Settlement of between 1mm and 5mm is predicted, with the greatest settlement at the building's western end (the rear). Due to the condition of this building, it is vulnerable to settlement, and although the damage assessment identifies the damage risk to be negligible, with the typical possibility of hairline cracks at a maximum of 0.1mm, there is potential for damage to the historic fabric of this building	Low	Minor adverse

Name / Significance	Description of effect	Magnitude of change	Significance of effect
Church of St Paul (High significance)	Ground settlement of between 1mm and 3mm is predicted, with the greatest settlement at its western (spire) end. The damage assessment identifies the damage risk category to be negligible with the possibility of cracks typically up to 0.1mm, however due to the poor condition of the churchyard boundary walls and the fragile and important decorative elements within the church, means there may be some impact to the significance of the building	Low	Minor adverse
LB Greenwich			
Greenwich Pumping Station (High significance)	This building would experience settlement of between 1mm and 30mm, with the greatest settlement at the east beam engine house, decreasing across the boiler room. The damage assessment considers that there is a damage risk category of moderate, with the potential for typical cracks up to 15mm and a deterioration in condition, and the heritage fabric of the east beam engine house may be permanently impacted due to damage to its structure	Medium	Moderate adverse
Bridges and Viaducts			
Hammersmith Bridge (High significance)	This bridge would experience a maximum settlement of 1mm. The damage assessment report (see Vol 3 Appendix E.1) states the potential damage risk be negligible, with the possibility of hairline cracks of a typical maximum width of 0.1mm. This would not affect the structural integrity of the bridge.	Negligible	Minor adverse
Putney Road Bridge (High significance)	The bridge would experience a maximum vertical movement beneath two piers of less than 8mm and 9mm, with horizontal movements of a maximum of 4.42mm at foundation level. The third pier of the bridge and the Putney abutment would experience less than 1mm of settlement. The damage assessment report (see Vol 3 Appendix E.1) identifies that vertical and radial movements are concentrated	Low	Minor adverse

Name / Significance	Description of effect	Magnitude of change	Significance of effect
	at pier one and two, and the intermediate spans, which would experience hogging[i]. The assessment has shown that the resulting minor tension would lead to the opening up of the joints between the arch voussoirs[ii] in the intermediate and abutment spans of the bridge. These cracks would not be sufficiently wide to affect the structural integrity of the bridge.		
Battersea Road Bridge (High significance)	This bridge would experience a maximum settlement of 17mm. The damage assessment report (see Vol 3 Appendix E.1) states the potential damage risk to be negligible, with the possibility of hairline cracks of a typical maximum width of 0.1mm. There may be slight damage to the significant cast iron and decorative elements of the superstructure of the bridge, although the structural integrity of the bridge would not be affected.	Low	Minor adverse
Albert Bridge (High significance)	The bridge would experience a concentration of settlement at its two northern piers, resulting in a maximum settlement of 17mm. The damage assessment states the damage risk to be negligible, with the possibility of hairline cracks of up to 0.1mm. It is not predicted that this level of settlement will have any structural impact upon the bridge.	Negligible	Minor adverse
Chelsea Bridge (High significance)	This bridge would experience a maximum settlement of 16mm. The damage assessment report (see Vol 3 Appendix E.1) states the potential damage risk to be negligible, with the possibility of hairline cracks of a typical maximum width of 0.1mm. However there may be small impact upon decorative elements, with no effects on the structural integrity of the bridge.	Low	Minor adverse
Vauxhall Road Bridge (High	This bridge would experience an approximate maximum vertical settlement of 8mm at pier 3 and 10mm at pier 4. The damage assessment report (see Vol 3 Appendix E.1) identifies a risk of hairline cracks of up to 0.1mm. This would not	Negligible	Minor adverse

[i] Hogging is where the middle of a beam or part of the structure would rise.

[ii] Voussioirs are the individual radiating masonry units of an arch, and are often wedge shaped.

Name / Significance	Description of effect	Magnitude of change	Significance of effect
significance)	affect the structural integrity of the bridge.		
Lambeth Road Bridge (High significance)	This bridge would experience a maximum settlement of approximately 7mm. The damage assessment states that cracking is unlikely to the piers and abutments and that movement would be transferred to the deck via bearings, Prior to the works the adequacy of the bearings would be checked and, if inadequate, would be made adequate. The structural integrity of the bridge would not be affected.	Negligible	Minor adverse
Westminster Bridge (High significance)	This bridge would experience a maximum vertical settlement of less than 9mm in piers two and three (from the west). The damage assessment identifies that generally cracking is expected to be hairline. This would not affect the structural integrity of the bridge.	Negligible	Minor adverse
Chelsea Rail Bridge (High significance)	The bridge would experience a maximum settlement of 6.5mm, concentrated on the first and second piers from the west. The damage assessment identifies the damage risk to the bridge to be negligible, with a slight risk of hairline cracking to surface finishes. The structural integrity of the bridge would not be affected.	Negligible	Minor adverse
Waterloo Road Bridge (High significance)	This bridge would experience a maximum vertical settlement of approximately 14.2mm at foundation level, concentrated at the third span from the north. The damage assessment identifies that cracking is expected to be hairline, with no impact upon the structural stability of the bridge.	Negligible	Minor adverse
Blackfriars Road Bridge (High significance)	The bridge would experience settlement concentrated to its northern end. The bridge is expected to experience total ground movements of up to approximately 6.1mm, resulting in a risk of negligible damage, with a risk of cracks typically up to 0.1mm in width. The structural integrity of the bridge would not be affected.	Negligible	Minor adverse
Southwark Road Bridge (High significance)	A maximum vertical settlement of 8mm is predicted to two piers of the bridge. The damage assessment report (see Vol 3 Appendix E.1) identifies the predicted damage risk category to be negligible, which typically means a risk of hairline cracks of up to 0.1mm. The structural integrity of the bridge would not be affected.	Negligible	Minor adverse

Name / Significance	Description of effect	Magnitude of change	Significance of effect
Tower Bridge (High significance)	A maximum vertical settlement of 12mm at foundation level is predicted. The damage assessment report (see Vol 3 Appendix E.1) predicts some rotation and displacement between each bascule, which may affect the operation of the nosing joints, which may need adjustment to allow the bascule leaves to close tightly. This would not damage the significance of the bridge. The predicted damage risk category is negligible, with the possibility of hairline cracks of a typical maximum width of 0.1mm. The structural integrity of the bridge would not be affected.	Negligible	Minor adverse
The Brunel Thames Tunnel, London Overground tunnel (High significance)	Differential settlement of the base slab of the tunnels likely to be 3.3mm. The damage assessment report (see Vol 3 Appendix E.1) predicts the damage risk to be negligible with the possibility of hairline cracks of a typical maximum width of 0.1mm. The structural integrity of the bridge would not be affected.	Negligible	Minor adverse
DLR Viaduct on Island Row (High significance)	The damage assessment report (see Vol 3 Appendix E.1) predicts that the viaduct would experience strains that are well below the tensile strain limit that would produce a damage risk category of negligible. There is therefore unlikely to be damage and any damage is likely to be negligible, with at most the possibility of hairline cracks of a typical maximum width of 0.1mm. The structural integrity of the viaduct would not be affected.	Negligible	Minor adverse
Browne House and Farrar House Viaduct – (High significance)	This section of viaduct would experience a maximum settlement of 6mm. The damage assessment report (see Vol 3 Appendix E.1) states the potential damage risk to be negligible, with the possibility of hairline cracks of a typical maximum width of 0.1mm. The structural integrity of the viaduct would not be affected.	Negligible	Minor adverse
Mechanic's Path Viaduct – (High	This section of viaduct would experience a maximum settlement of between 2mm and 3mm. The damage assessment report states the potential damage risk to be negligible, with the possibility of hairline cracks of a typical maximum width of	Negligible	Minor adverse

Name / Significance	Description of effect	Magnitude of change	Significance of effect
significance)	0.1mm. The structural integrity of the viaduct would not be affected.		
Hart's Wharf Viaduct – (High significance)	This section of viaduct would experience a maximum settlement of 4mm. The damage assessment report states the potential damage risk to be negligible, with the possibility hairline cracks of a typical maximum width of 0.1mm. The structural integrity of the viaduct would not be affected.	Negligible	Minor adverse
Deptford Creek Lifting Bridge – (High significance)	The predicted maximum vertical settlement at the abutments would be less than 5mm, with the maximum differential vertical settlement between the east abutment and the central pier being 0.7mm and that between the central pier and the west abutment being 0.6mm. The maximum differential movement perpendicular to the span would be 2.2mm. The damage risk identified as negligible, which typically means a risk of hairline cracks of 0.1mm. The structural integrity of the viaduct would not be affected.	Negligible	Minor adverse
Sun Wharf Viaduct (High significance)	This section of viaduct would experience a maximum settlement of 6mm. The damage assessment report states that the predicted damage to the viaduct is negligible with even hairline cracking unlikely. The structural integrity of the viaduct would not be affected.	Negligible	Minor adverse
Twelve Trees Crescent Road Bridge – (High significance)	This bridge would experience a maximum of 15.7mm vertical movement beneath the pier foundation, with the tunnel running obliquely beneath the central pier. The damage assessment report (see Vol 3 Appendix E.1) states that design of the bridge is such that it can absorb such movements without loss of significance. The structural integrity of the viaduct would not be affected.	Negligible	Minor adverse

7.5.4 There would be a **moderate adverse** effect to Lots Road Pumping Station due to the possibility of cracking up to 15mm at the rear of the building.

7.5.5 There would also be a **moderate adverse** effect to Greenwich Pumping Station due to the potential damage to the East Beam Engine House.

7.5.6 There would also be a **moderate adverse** effect to the Victoria Embankment river wall at Blackfriars Bridge Foreshore.

7.5.7 There would be a **minor adverse** effect to three Grade II listed buildings which are on the English Heritage 'Buildings at Risk' register (227 Deptford High Street, 777-783 Commercial Road, Limehouse District Library) due to their current condition. Although the buildings are not predicted to be subject to high levels of damage, their features and finishes are at risk of damage due to their fragility and the lack of maintenance, although predicted movements are small.

7.5.8 The remainder of the listed buildings and structures all have a negligible or low damage risk, resulting in a **minor adverse** effect to these assets of high significance.

7.6 Operational effects assessment

7.6.1 As stated in para. 7.1.6, settlement is instigated by construction activity and hence all the effects are assessed within the construction phase. There is therefore no operational phase assessment.

7.7 Cumulative effects assessment

Construction effects

7.7.1 The only relevant scheme identified in the site development schedule (Appendix N of site assessment volumes) for cumulative project-wide effects is the Crossrail scheme, as the construction phase for Crossrail would be completed during the construction period for the Thames Tideway Tunnel project. The Crossrail tunnels would cross the route of the main tunnel in LB Tower Hamlets at Limehouse. The main tunnel would be considerably deeper than the Crossrail tunnel in this area. Both tunnels would run beneath the Grade II Listed DLR viaduct on Island Row.

7.7.2 The settlement caused by the Crossrail tunnel is likely to cause at worst minor adverse damage to the listed viaduct. The Thames Tideway Tunnel project would cause strains to the viaduct that are well below the tensile strain limit that would produce a damage risk category of negligible. It is therefore unlikely that there would be an elevated effect to the significance if the structure and the effect would remain **minor adverse**.

7.7.3 None of the other schemes identified in the site development schedule (Appendix N of site assessment volumes) as being schemes to be considered under the assessment of cumulative effects, would cause damage to heritage assets that would be affected by the Thames Tideway Tunnel project. There is therefore no project-wide cumulative assessment relating to these schemes.

7.8 Mitigation

7.8.1 Section 13.2 of *CoCP Part A* requires contactors to design and carry out construction of the project in a manner that would minimise the impact on third-party infrastructure and buildings as a result of ground movement and other construction related activities. The contractors would also utilise best practice methods to reduce, control and limit ground movement, including the selection of suitable tunnelling techniques and the selection and operation of modern tunnel boring machines.

7.8.2 It is intended that the least possible loss of significance is experienced by heritage assets due to ground movement. Therefore, the least intrusive or damaging mitigation measures would be chosen, except in cases where the predicted detrimental effect due to ground movement is judged to be greater than that caused by intrusive mitigation. There are a number of mitigation options that could be utilised for the control of settlement to buildings during construction.

7.8.3 The listed buildings and structures would be monitored prior to, during, and following the construction works, to ensure that any damage is noted and rectified and to ensure that the actual movements are within predicted and acceptable limits. In the unlikely event that a listed building or structure should become unstable during construction, emergency works such as temporary propping or intrusive wall ties would take place to ensure the heritage asset does not deteriorate. Any other minor damage, such as surface cracking and slight deterioration of finishes, arising from ground movement would be repaired using appropriate conservation techniques following the conclusion of the proposed works. Repairs of damage to significant features and finishes following the significant ground movement would provide appropriate mitigation for the damage that is predicted.

7.8.4 In one case only is specific mitigation proposed beyond post-construction repair; this is to Tower Bridge, where the predicted rotation between bascule elements may require the adjustment of bascule nosing joints to ensure the continued operation of the bridge. This adjustment in itself would not affect the heritage significance of the bridge, and would mitigate any potential impact on the operation of the bridge caused by ground movements.

7.8.5 Intrusive mitigation could be applied to the buildings such as ties, pre-construction repairs, or underpinning. These options are generally deployed in instances where the predicted damage risk is greater than that predicted to result from the project-wide settlement, or where buildings are particularly at risk of failure, as the installation of these forms of mitigation could cause more damage to the listed building's significance than the damage predicted from the tunnelling works. Therefore these types of intrusive mitigation to heritage assets affected by settlement are not proposed. Only where at least partial structural failure or significant permanent damage to significance is anticipated would such measures be used.

7.8.6 Ground mitigation takes the form of grouting underneath buildings. Grout is introduced into the ground by long grouting sleeves, called Tube a manchette, which are drilled into the ground. The Tube a manchette, which are controlled by movement monitoring of the ground and surrounding buildings, pump grout where necessary into the ground, redressing changes in ground condition and reducing heave or settlement. The installation of Tube a manchette has the potential to cause up to 20mm of ground movement; this is considerably more than the ground movement predicted to be induced to most listed buildings during construction of the Thames Tideway Tunnel project. The depth of the tunnel relative to the infrastructure means that no requirement to use this type of mitigation has been identified on the project.

7.9 Residual effects assessment

Construction effects

7.9.1 It has been assessed that the maximum extent of any potential post-construction damage repairs to the significant features and finishes of listed buildings and structures is as follows:

7.9.2 There would be a **minor adverse** residual effect on Chelsea, Battersea Road, and Putney bridges.

7.9.3 There would be a **negligible** residual effect on Tower Bridge following the mitigation to the bascule nosing joints.

7.9.4 There would be a **minor adverse** residual effect on Victoria Embankment river wall at Blackfriars Brdge Foreshore following post-construction repair.

7.9.5 There would be a **negligible** residual effect to St Paul's Church following mitigation comprising of post-construction repair of hairline cracking to the decorative elements, unless repair to hairline cracking is likely to cause more damage to significance than the hairline cracking, in which case hairline cracking would not be repaired.

7.9.6 There would be a **minor adverse** residual effect on Lots Road Pumping Station following post-construction repair of cracking to the rear of the building.

7.9.7 There would be a **minor adverse** residual effect on Greenwich Pumping Station following post-construction repair.

7.10 Project-wide effects assessment summary

Vol 3 Table 7.10.1 Ground movement impacts on the historic environment – summary of construction assessment

Receptor and value	Effect	Significance of effect	Mitigation	Significance of residual effect
LB Hounslow				
60-62 Bath Road (High)	Settlement	Minor adverse	Any damage to significance would be repaired using appropriate conservation methods following the conclusion of the proposed works	Negligible
Swan House (High)	Settlement	Minor adverse	Any damage to significance would be repaired using appropriate conservation methods following the conclusion of the proposed works	Negligible
Cedar House (High)	Settlement	Minor adverse	Any damage to significance would be repaired using appropriate conservation methods following the conclusion of the proposed works	Negligible
LB Kensington and Chelsea				
Lots Road Pumping Station (High	Settlement	Moderate adverse	As with other listed buildings, the building would be monitored during the works, in accordance with CoCP and any damage to significance would be repaired using appropriate conservation methods following the conclusion of the works	Minor adverse
LB Wandsworth				
7-9 Church Row (High)	Settlement	Minor adverse	Any damage to significance would be repaired using appropriate conservation methods following the conclusion of the proposed works	Negligible

Receptor and value	Effect	Significance of effect	Mitigation	Significance of residual effect
1-6 Church Row (High)	Settlement	Minor adverse	Any damage to significance would be repaired using appropriate conservation methods following the conclusion of the proposed works	Negligible
Wentworth House (High)	Settlement	Minor adverse	Any damage to significance would be repaired using appropriate conservation methods following the conclusion of the proposed works	Negligible
City of Westminster				
Victoria Embankment river wall (High)	Settlement	Minor adverse	Any damage to significance would be repaired using appropriate conservation methods following the conclusion of the proposed works	Negligible
City of London				
Hamilton House (High)	Settlement	Minor adverse	Any damage to significance would be repaired using appropriate conservation methods following the conclusion of the proposed works	Negligible
Telephone House (High)	Settlement	Minor adverse	Any damage to significance would be repaired using appropriate conservation methods following the conclusion of the proposed works	Negligible
Sion House (High)	Settlement	Minor adverse	Any damage to significance would be repaired using appropriate conservation methods following the conclusion of the proposed works	Negligible
9 Carmelite Street (High)	Settlement	Minor adverse	Any damage to significance would be repaired using appropriate conservation methods following the conclusion of the proposed works	Negligible
Carmelite House (High)	Settlement	Minor adverse	Any damage to significance would be repaired using appropriate conservation methods following the	Negligible

Receptor and value	Effect	Significance of effect	Mitigation	Significance of residual effect
			conclusion of the proposed works	
Victoria Embankment river wall (High)	Settlement	Moderate adverse	Any damage to significance would be made good with repairs using standard conservation methods, to achieve like for like repair. As with other buildings, the building would be monitored.	Minor adverse
LB Southwark				
Corbetts Wharf (High)	Settlement	Minor adverse	Any damage to significance would be repaired using appropriate conservation methods following the conclusion of the proposed works	Negligible
Chambers Wharf (High)	Settlement	Minor adverse	Any damage to significance would be repaired using appropriate conservation methods following the conclusion of the proposed works	Negligible
33 Bermondsey Wall East (High)	Settlement	Minor adverse	Any damage to significance would be repaired using appropriate conservation methods following the conclusion of the proposed works	Negligible
LB Tower Hamlets				
Free Trade Wharf (High)	Settlement	Minor adverse	Any damage to significance would be repaired using appropriate conservation methods following the conclusion of the proposed works	Negligible
Prospect of Whitby (High)	Settlement	Minor adverse	Any damage to significance would be repaired using appropriate conservation methods following the conclusion of the proposed works	Negligible
BW Customs House (High)	Settlement	Minor adverse	Any damage to significance would be repaired using appropriate conservation methods following the conclusion of the proposed works	Negligible

Receptor and value	Effect	Significance of effect	Mitigation	Significance of residual effect
British Sailor's Society (High)	Settlement	Minor adverse	Any damage to significance would be repaired using appropriate conservation methods following the conclusion of the proposed works	Negligible
Limehouse Town Hall (High)	Settlement	Minor adverse	Any damage to significance would be repaired using appropriate conservation methods following the conclusion of the proposed works	Negligible
Limehouse District Library (High)	Settlement	Minor adverse	Any damage to significance would be repaired using appropriate conservation methods following the conclusion of the proposed works	Negligible
Dowgate Wharf (High)	Settlement	Minor adverse	Any damage to significance would be repaired using appropriate conservation methods following the conclusion of the proposed works	Negligible
777-783 Commercial Road (High)	Settlement	Minor adverse	Any damage to significance would be repaired using appropriate conservation methods following the conclusion of the proposed works	Negligible
Block A, Metropolitan Wharf (High)	Settlement	Minor adverse	Any damage to significance would be repaired using appropriate conservation methods following the conclusion of the proposed works	Negligible
Block B&C, Metropolitan Wharf (High)	Settlement	Minor adverse	Any damage to significance would be repaired using appropriate conservation methods following the conclusion of the proposed works	Negligible
Block D, Metropolitan Wharf (High)	Settlement	Minor adverse	Any damage to significance would be repaired using appropriate conservation methods following the conclusion of the proposed works	Negligible
Rotherhithe Tunnel Air Shaft (High)	Settlement	Minor adverse	Any damage to significance would be repaired using appropriate conservation methods following the	Negligible

Receptor and value	Effect	Significance of effect	Mitigation	Significance of residual effect
			conclusion of the proposed works	
Wall to St Anne's House (High)	Settlement	Minor adverse	Any damage to significance would be repaired using appropriate conservation methods following the conclusion of the proposed works	Negligible
Limehouse Accumulator Tower (High)	Settlement	Minor adverse	Any damage to significance would be repaired using appropriate conservation methods following the conclusion of the proposed works	Negligible
LB Lewisham				
Deptford Fire Station (High)	Settlement	Minor adverse	Any damage to significance would be repaired using appropriate conservation methods following the conclusion of the proposed works	Negligible
227 Deptford High Street (High)	Settlement	Minor adverse	Any damage to significance would be repaired using appropriate conservation methods following the conclusion of the proposed works	Negligible
Church of St Paul (High)	Settlement	Minor adverse	Any damage to significance would be repaired using appropriate conservation methods following the conclusion of the proposed works	Negligible
LB Greenwich				
Greenwich Pumping Station (High	Settlement	Moderate adverse	Damage to significance would be made good with repairs using standard conservation methods, to achieve like for like repair. As with other buildings, the building would be monitored.	Minor adverse
Bridges and Viaducts				
Hammersmith Bridge (High)	Settlement	Minor adverse	Any damage to significance would be repaired using appropriate conservation methods following the	Negligible

Receptor and value	Effect	Significance of effect	Mitigation	Significance of residual effect
			conclusion of the proposed works	
Putney Bridge (High)	Settlement	Minor adverse	Volume loss control would be implemented, emergency repairs would be effected where needed, and other repairs to damage would take place following completion of the works, using standard conservation techniques.	Negligible
Battersea Road Bridge (High)	Settlement	Minor adverse	Any damage to significance would be repaired using appropriate conservation methods following the conclusion of the proposed works	Negligible
Albert Bridge (High)	Settlement	Minor adverse	Any damage to significance would be repaired using appropriate conservation methods following the conclusion of the proposed works	Negligible
Chelsea Bridge (High)	Settlement	Minor adverse	Any damage to significance would be repaired using appropriate conservation methods following the conclusion of the proposed works	Negligible
Vauxhall Bridge (High)	Settlement	Minor adverse	Any damage to significance would be repaired using appropriate conservation methods following the conclusion of the proposed works	Negligible
Lambeth Road Bridge (High)	Settlement	Minor adverse	Any damage to significance would be repaired using appropriate conservation methods following the conclusion of the proposed works	Negligible
Westminster Bridge (High)	Settlement	Minor adverse	Any damage to significance would be repaired using appropriate conservation methods following the conclusion of the proposed works	Negligible
Chelsea Rail Bridge (High)	Settlement	Minor adverse	Any damage to significance would be repaired using appropriate conservation methods following the conclusion of the proposed works	Negligible

Receptor and value	Effect	Significance of effect	Mitigation	Significance of residual effect
Waterloo Bridge (High)	Settlement	Minor adverse	Any damage to significance would be repaired using appropriate conservation methods following the conclusion of the proposed works	Negligible
Blackfriars Road Bridge (High)	Settlement	Minor adverse	Any damage to significance would be repaired using appropriate conservation methods following the conclusion of the proposed works	Negligible
Southwark Bridge (High)	Settlement	Minor adverse	Any damage to significance would be repaired using appropriate conservation methods following the conclusion of the proposed works	Negligible
Tower Bridge (High)	Settlement	Minor adverse	Pre-construction adjustment to bascule nosing joints to accommodate movement during settlement	Negligible
The Brunel Thames Tunnel, London Overground tunnel (High)	Settlement	Minor adverse	Any damage to significance would be repaired using appropriate conservation methods following the conclusion of the proposed works	Negligible
DLR Viaduct on Island Row (High)	Settlement	Minor adverse	Any damage to significance would be repaired using appropriate conservation methods following the conclusion of the proposed works	Negligible
Browne House and Farrar House Viaduct (High)	Settlement	Minor adverse	Any damage to significance would be repaired using appropriate conservation methods following the conclusion of the proposed works	Negligible
Mechanic's Path Viaduct (High)	Settlement	Minor adverse	Any damage to significance would be repaired using appropriate conservation methods following the conclusion of the proposed works	Negligible
Hart's Wharf Viaduct	Settlement	Minor	Any damage to significance would be repaired using appropriate conservation methods following the	Negligible

Receptor and value	Effect	Significance of effect	Mitigation	Significance of residual effect
(High)		adverse	conclusion of the proposed works	
Deptford Creek Lifting Bridge (High)	Settlement	Minor adverse	Any damage to significance would be repaired using appropriate conservation methods following the conclusion of the proposed works	Negligible
Sun Wharf Viaduct (High)	Settlement	Minor adverse	Any damage to significance would be repaired using appropriate conservation methods following the conclusion of the proposed works	Negligible
Twelve Trees Crescent Bridge (High)	Settlement	Minor adverse	Any damage to significance would be repaired using appropriate conservation methods following the conclusion of the proposed works	Negligible

7.11 Summary of significant effects at all sites

7.11.1 Significant effects, comprising moderate or major adverse or beneficial effects, on heritage assets have been identified at a number of sites during construction and operation. Significant adverse effects during construction include effects on the setting of heritage assets, and physical effects from the complete or partial removal of structures and remains, either temporarily or permanently, and from effects of ground movement associated with the tunnel and other deep excavations. During construction, effects specifically at foreshore sites include effects on buried remains from compression of foreshore deposits and from possible scour around temporary structures.

7.11.2 Significant beneficial operational effects on the settings of heritage assets have been identified at Chelsea Embankment Foreshore (see Vol 13 Section 7), Carnwath Road Riverside (see Vol 10 Section 7), Deptford Church Street (see Vol 23 Section 7) and King Edward Memorial Park (see Vol 21 Section 7).

7.11.3 Vol 3 Table 7.11.1 provides a summary of the significant effects identified at individual sites across the project. Mitigation measures have been identified and have been described where relevant within Section 7 of Vols 4 to 27. These effects are also included in the project-wide assessment and do not constitute additional effects.

Vol 3 Table 7.11.1 Historic environment – summary of likely significant effects at all sites

Significance of effect	Receptor	Description of effect	Sites with significant effects (pre-mitigation)	Sites with significant residual effects
Construction - adverse	Palaeoenviron-mental remains	Removal	Albert Embankment Foreshore (Vol 16 Section 7) Chambers Wharf (Vol 20 Section 7)	None
		Compression	Albert Embankment Foreshore (Vol 16 Section 7) Chambers Wharf (Vol 20 Section 7)	None
		Scour around temporary structures	Albert Embankment Foreshore (Vol 16 Section 7) Chambers Wharf (Vol 20 Section 7)	None
	Prehistoric activity or settlement	Removal	Albert Embankment Foreshore (Vol 16 Section 7) Abbey Mills Pumping Station (Vol 25 Section 7) Barn Elms (Vol 6 Section 7) Chelsea Embankment Foreshore (Vol 13 Section 7) Chambers Wharf (Vol 20 Section 7) Carnwath Road Riverside (Vol 10 Section 7) Cremorne Wharf Depot (Vol 12 Section 7) Dormay Street (Vol 8 Section 10) Earl Pumping Station (Vol 22 Section 7) Falconbrook Pumping Station (Vol 11 Section 7) Hammersmith Pumping Station (Vol 5 Section 7) Heathwall Pumping Station (Vol 15 Section 7) King Edward Memorial Park Foreshore (Vol 21 Section 7) King George's Park (Vol 9 Section 7) Kirtling Street (Vol 14 Section 7) Bekesbourne Street (Vol 27 Section 7) Shad Thames Pumping Station (Vol 19 Section 7)	None

Significance of effect	Receptor	Description of effect	Sites with significant effects (pre-mitigation)	Sites with significant residual effects
		Compression	Albert Embankment Foreshore (Vol 16 Section 7) Chambers Wharf (Vol 20 Section 7) Chelsea Embankment Foreshore (Vol 13 Section 7) Heathwall Pumping Station (Vol 15 Section 7) King Edward Memorial Park Foreshore (Vol 21 Section 7)	None
		Scour around temporary structures	Albert Embankment Foreshore (Vol 16 Section 7) Chambers Wharf (Vol 20 Section 7) Chelsea Embankment Foreshore (Vol 13 Section 7) Heathwall Pumping Station (Vol 15 Section 7) King Edward Memorial Park Foreshore (Vol 21 Section 7)	None
	Roman remains	Removal	Blackfriars Bridge Foreshore (Vol 18 Section 7) Chambers Wharf (Vol 20 Section 7) King Edward Memorial Park Foreshore (Vol 21 Section 7) King George's Park (Vol 9 Section 7) Putney Embankment Foreshore (Vol 7 Section 7) Shad Thames Pumping Station (Vol 19 Section 7)	None
		Compression	Blackfriars Bridge Foreshore (Vol 18 Section 7) Chambers Wharf (Vol 20 Section 7) King Edward Memorial Park Foreshore (Vol 21 Section 7) Putney Embankment Foreshore (Vol 7 Section 7)	None
		Scour around temporary structures	Blackfriars Bridge Foreshore (Vol 18 Section 7) Chambers Wharf (Vol 20 Section 7) King Edward Memorial Park Foreshore (Vol 21 Section 7)	None

Significance of effect	Receptor	Description of effect	Sites with significant effects (pre-mitigation)	Sites with significant residual effects
			Putney Embankment Foreshore (Vol 7 Section 7)	
	Early medieval (Saxon) fish traps or other remains	Removal	Chambers Wharf (Vol 20 Section 7) Chelsea Embankment Foreshore (Vol 13 Section 7) Cremorne Wharf Depot (Vol 12 Section 7) Hammersmith Pumping Station (Vol 5 Section 7) Heathwall Pumping Station (Vol 15 Section 7) King Edward Memorial Park Foreshore (Vol 21 Section 7) King George's Park (Vol 9 Section 7) Kirtling Street (Vol 14 Section 7) Putney Embankment Foreshore (Vol 7 Section 7)	None
		Compression	Chambers Wharf (Vol 20 Section 7) Chelsea Embankment Foreshore (Vol 13 Section 7) Heathwall Pumping Station (Vol 15 Section 7) King Edward Memorial Park Foreshore (Vol 21 Section 7) Putney Embankment Foreshore (Vol 7 Section 7)	None
		Scour around temporary structures	Chambers Wharf (Vol 20 Section 7) Chelsea Embankment Foreshore (Vol 13 Section 7) Heathwall Pumping Station (Vol 15 Section 7) King Edward Memorial Park Foreshore (Vol 21 Section 7) Putney Embankment Foreshore (Vol 7 Section 7)	None
	Later medieval remains e.g. reclamation and flood	Removal	Blackfriars Bridge Foreshore (Vol 18 Section 7) Barn Elms (Vol 6 Section 7) Chambers Wharf (Vol 20 Section 7) Cremorne Wharf Depot (Vol 12 Section 7) Dormay Street (Vol 8 Section 10)	None

Significance of effect	Receptor	Description of effect	Sites with significant effects (pre-mitigation)	Sites with significant residual effects
	defence		Falconbrook Pumping Station (Vol 11 Section 7) Hammersmith Pumping Station (Vol 5 Section 7) King Edward Memorial Park Foreshore (Vol 21 Section 7) King George's Park (Vol 9 Section 7) Putney Embankment Foreshore (Vol 7 Section 7) Shad Thames Pumping Station (Vol 19 Section 7)	
		Compression	Blackfriars Bridge Foreshore (Vol 18 Section 7) Chambers Wharf (Vol 20 Section 7) King Edward Memorial Park Foreshore (Vol 21 Section 7) Putney Embankment Foreshore (Vol 7 Section 7)	None
		Scour around temporary structures	Blackfriars Bridge Foreshore (Vol 18 Section 7) Chambers Wharf (Vol 20 Section 7) King Edward Memorial Park Foreshore (Vol 21 Section 7) Putney Embankment Foreshore (Vol 7 Section 7)	None
	Post-medieval 18th and 19th century remains, including the footings of industrial buildings and yards, former river walls, infilled docks	Removal	Blackfriars Bridge Foreshore (Vol 18 Section 7) Chambers Wharf (Vol 20 Section 7) Chelsea Embankment Foreshore (Vol 13 Section 7) Cremorne Wharf Depot (Vol 12 Section 7) Dormay Street (Vol 8 Section 10) Greenwich Pumping Station (Vol 24 Section 7) Heathwall Pumping Station (Vol 15 Section 7) King Edward Memorial Park Foreshore (Vol 21 Section 7) Kirtling Street (Vol 14 Section 7) Putney Embankment Foreshore (Vol 7 Section 7)	None

Significance of effect	Receptor	Description of effect	Sites with significant effects (pre-mitigation)	Sites with significant residual effects
	and barge beds		Victoria Embankment Foreshore (Vol 17 Section 7)	
		Compression	Blackfriars Bridge Foreshore (Vol 18 Section 7) Chambers Wharf (Vol 20 Section 7) Chelsea Embankment Foreshore (Vol 13 Section 7) Heathwall Pumping Station (Vol 15 Section 7) King Edward Memorial Park Foreshore (Vol 21 Section 7) Putney Embankment Foreshore (Vol 7 Section 7)	None
		Scour around temporary structures	Blackfriars Bridge Foreshore (Vol 18 Section 7) Chambers Wharf (Vol 20 Section 7) Chelsea Embankment Foreshore (Vol 13 Section 7) Heathwall Pumping Station (Vol 15 Section 7) King Edward Memorial Park Foreshore (Vol 21 Section 7) Putney Embankment Foreshore (Vol 7 Section 7)	None
	Above ground heritage assets of high significance	Removal of whole asset/part of fabric	Blackfriars Bridge Foreshore (Vol 18 Section 7) Chelsea Embankment Foreshore (Vol 13 Section 7) Greenwich Pumping Station (Vol 24 Section 7) Putney Embankment Foreshore (Vol 7 Section 7) Victoria Embankment Foreshore (Vol 17 Section 7)	Blackfriars Bridge Foreshore (Vol 18 Section 7) Chelsea Embankment Foreshore (Vol 13 Section 7) Putney Embankment Foreshore (Vol 7 Section 7) Victoria Embankment Foreshore (Vol 17

Significance of effect	Receptor	Description of effect	Sites with significant effects (pre-mitigation)	Sites with significant residual effects
				Section 7)
		Ground movement	Blackfriars Bridge Foreshore (Vol 18 Section 7) Cremorne Wharf Depot (Vol 12 Section 7) Greenwich Pumping Station (Vol 24 Section 7) Putney Embankment Foreshore (Vol 7 Section 7)	None
		Effect on character, appearance and / or setting	Albert Embankment Foreshore (Vol 16 Section 7) Blackfriars Bridge Foreshore (Vol 18 Section 7) Chelsea Embankment Foreshore (Vol 13 Section 7) Carnwath Road Riverside (Vol 10 Section 7) Deptford Church Street (Vol 23 Section 7) King Edward Memorial Park Foreshore (Vol 21 Section 7) Putney Embankment Foreshore (Vol 7 Section 7) Shad Thames Pumping Station (Vol 19 Section 7) Victoria Embankment Foreshore (Vol 17 Section 7)	Albert Embankment Foreshore (Vol 16 Section 7) Blackfriars Bridge Foreshore (Vol 18 Section 7) Chelsea Embankment Foreshore (Vol 13 Section 7) Carnwath Road Riverside (Vol 10 Section 7) Deptford Church Street (Vol 23 Section 7) King Edward Memorial Park Foreshore (Vol 21 Section 7) Putney Embankment Foreshore (Vol 7 Section 7) Shad Thames Pumping Station (Vol 19 Section 7)

Significance of effect	Receptor	Description of effect	Sites with significant effects (pre-mitigation)	Sites with significant residual effects
				Victoria Embankment Foreshore (Vol 17 Section 7)
	Above ground heritage assets of medium significance	Removal of whole asset/part of fabric	Albert Embankment Foreshore (Vol 16 Section 7) Blackfriars Bridge Foreshore (Vol 18 Section 7) Chelsea Embankment Foreshore (Vol 13 Section 7) Dormay Street (Vol 8 Section 10) King George's Park (Vol 9 Section 7) Kirtling Street (Vol 14 Section 7) Shad Thames Pumping Station (Vol 19 Section 7)	None
Operation - adverse	Above ground heritage assets of high significance	Effect on character, appearance and / or setting	Blackfriars Bridge Foreshore (Vol 18 Section 7) Chelsea Embankment Foreshore (Vol 13 Section 7)	Blackfriars Bridge Foreshore (Vol 18 Section 7) Chelsea Embankment Foreshore (Vol 13 Section 7)
Operation - beneficial	Above ground heritage assets of high significance	Effect on character, appearance and / or setting	Chelsea Embankment Foreshore (Vol 13 Section 7) Deptford Church Street (Vol 23 Section 7) Greenwich Pumping Station (Vol 24 Section 7)	Chelsea Embankment Foreshore (Vol 13 Section 7) Deptford Church Street (Vol 23 Section 7) Greenwich Pumping

Significance of effect	Receptor	Description of effect	Sites with significant effects (pre-mitigation)	Sites with significant residual effects
				Station (Vol 24 Section 7)
	Above ground heritage assets of medium significance	Effect on character, appearance and / or setting	King Edward Memorial Park Foreshore (Vol 21 Section 7)	King Edward Memorial Park Foreshore (Vol 21 Section 7)

References

[1] Planning (Listed Buildings and Conservation Areas) Act 1990, Section 1.

[2] Burland, J, B. *Proceedings of the First International Conference on Earthquake Geotechnical Engineering*, Assessment of Risk of Damage due to Tunnelling and Excavation (1995).

[3] Burland, J, B. See citation above.

[4] English Heritage. *Heritage at Risk Register*. Available at: http:// risk.english-heritage.org.uk/register.aspx last accessed December 2012.

[5] English Heritage. See citation above.

This page is intentionally blank

Thames Tideway Tunnel
Thames Water Utilities Limited

Application for Development Consent

Application Reference Number: WWO10001

Environmental Statement

Doc Ref: **6.2.03**

Volume 3: Project-wide effects assessment

Section 8: Land quality

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

Hard copy available in

Box **17** Folder **A**
January 2013

Thames Tideway Tunnel
Creating a cleaner, healthier River Thames

This page is intentionally blank

Thames Tideway Tunnel

Environmental Statement

Volume 3: Project-wide effects assessment

Section 8: Land quality

List of contents

Page number

This page is intentionally blank

8 Land quality

8.1 Introduction

8.1.1 Project-wide construction and operational effects related to land quality have been scoped out as explained in Volume 2 Section 8. This is on the basis that no significant effects are anticipated during either construction or operation beyond those assessed at a site level.

8.1.2 This section nevertheless presents details of engagement and an overview of the reasons why project-wide effects (as defined in this *Environmental Statement*) have been scoped out and a summary of the significant effects identified at individual sites across the project.

8.1.3 Project-wide likely significant effects on groundwater are reported in Section 13.

8.2 Engagement

8.2.1 Volume 2 documents the overall engagement which has been undertaken in preparing the *Environmental Statement*. No specific comments relevant to the assessment of project-wide effects on land quality have been received.

8.3 Overview

8.3.1 Land quality effects relate to the disturbance of contaminated ground within the construction sites. Any soil based contamination encountered is likely to be found within the upper geology at any given site (Made Ground, Alluvium and the River Terrace Deposits). The embedded construction measures, detailed in the *Code of Construction Practice (CoCP)*[i], would ensure that any contamination, within the development footprint, would be addressed in agreement with the Environment Agency and local authorities.

8.3.2 The nature of predicted land quality effects is such that they would be localised to within the assessment areas considered on the site assessments (see Vols 4 to 27 Section 8).

8.3.3 The likely significant effects of the project on groundwater are addressed in the project-wide groundwater assessment (see Section 13) and within the groundwater site assessments (see Vols 4 to 27 Section 13).

8.3.4 Therefore no project-wide assessment has been undertaken for this topic.

[i] The *Code of Construction Practice (CoCP)* is provided in Vol 1 Appendix A. It contains general requirements (Part A), and site specific requirements (Part B).

8.4 Summary of significant effects at all sites

8.4.1 No significant adverse effects on land quality have been identified at any of the Thames Tideway Tunnel sites. As no significant effects are anticipated, no mitigation measures have been proposed and therefore the significance of residual effects would remain unchanged.

8.4.2 As explained in Section 8.3 above, effects identified at individual sites would not result in project-wide effects (as defined in this *Environmental Statement*) when considered together across the whole project area.

Thames Tideway Tunnel
Thames Water Utilities Limited

Application for Development Consent

Application Reference Number: WWO10001

Environmental Statement

Doc Ref: **6.2.03**

Volume 3: Project-wide effects assessment

Section 9: Noise and vibration

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

Hard copy available in

Box **17** Folder **A**
January 2013

Thames Tideway Tunnel
Creating a cleaner, healthier River Thames

This page is intentionally blank

Thames Tideway Tunnel

Environmental Statement

Volume 3: Project-wide effects assessment

Section 9: Noise and vibration

List of contents

Page number

List of tables

Page number

9 Noise and vibration

9.1 Introduction

9.1.1 This section presents the findings of the assessment of the likely significant project-wide effects on noise and vibration resulting from the underground works required to construct the:

a. main tunnel (from Acton Storm Tanks to Abbey Mills Pumping Station)

b. long connection tunnels:

  i Frogmore long connection tunnel

  ii Greenwich long connection tunnel

c. short connection tunnels[i]

  i Hammersmith Pumping Station

  ii Falconbrook Pumping Station.

9.1.2 Groundborne vibration created by below ground construction activities propagates through the ground to surrounding buildings where it results in vibration of floors, walls and ceilings; which can also sometimes be heard as a low frequency ‘rumbling’ noise (called groundborne noise).

9.1.3 This assessment considers the operation of Tunnel Boring Machines (TBMs) and the temporary construction railways (TCRs) serving the TBMs.

9.1.4 The assessment has been undertaken at three types of properties; residential receptors, non-residential receptors and non-residential receptors which are particularly sensitive to vibration[ii]. The assessment has scoped out effects on infrastructure such as bridges, London Underground tunnels or utilities. This is because such infrastructure is not as sensitive to groundborne vibration as residential receptors which are in close proximity to each of the construction sites. For example, an impact at a residential receptor is identified at 3mm/s whereas guidance from BS 5228: Part 2: 2009 recommends a conservative criterion of 15mm/s for continuous vibrations at underground services, and between 15mm/s and 50mm/s for reinforced or framed structures such as bridges. The *Settlement information paper*, which accompanies the application for development consent (the ‘application’), and the *Code of Construction Practice (CoCP)*[iii] Part A Section 13 contain further information on these assets and the process for asset protection.

9.1.5 The noise and vibration from the surface construction sites serving the tunnelling activities are considered within the relevant site volumes (see

---

[i] The short connection tunnels have only been assessed at these two sites as they run beneath sensitive properties. Short connection tunnels at other sites either run beneath the River Thames or beneath properties of low sensitivity to groundborne noise and vibration where it is considered, there would be no effects on properties.

[ii] The latter have only been assessed for groundborne vibration.

[iii] The *Code of Construction Practice (CoCP)* is provided in Vol 1 Appendix A. It contains general requirements (Part A), and site-specific requirements (Part B).

Section 9 of Vols 4 to 27). Cumulative noise and vibration from surface construction site and the tunnelling activities are considered in Section 9.7.

9.1.6 Plans of the proposed tunnels alignment as well as figures included in the assessment of project-wide effects are contained in a separate volume (Volume 3 Project-wide effects assessment figures).

9.1.7 Operational project-wide effects for noise and vibration have not been assessed. Noise from storm water flowing through the main tunnel would not be noticeable as the only route for noise to leave the system would be at the shafts at specific sites. The site-specific assessment volumes (Section 9 of Vols 4 to 27) consider noise and vibration generated during the tunnel filling events, by the equipment required to control and ventilate the tunnels and by the maintenance operations. As no significant operational effects are considered likely at the surface sites, significant operational effects are not considered likely at the project-wide scale and for this reason, only information relating to construction is presented in this assessment of effects.

9.1.8 A summary of significant effects identified at the site-specific level across the project is provided in Section 9.11.

9.1.9 A sensitivity test undertaken for the highway network is contained in Vol 3 Appendix J.

9.2 Proposed development relevant to noise and vibration

9.2.1 The proposed development is described in Section 3 of this volume, with further details of each site described in Vols 4 to 27. The elements of the proposed development relevant to noise and vibration are set out below.

Construction

9.2.2 The construction of the tunnels would be undertaken on a continuous basis and therefore tunnelling and tunnelling support activities would be undertaken during the day, evening and night time periods.

Tunnel boring machines (TBM)

9.2.3 The rotating head of the TBM would ‘cut’ through the ground, potentially generating groundborne noise and vibration impacts. These impacts could occur for short periods of time (a matter of days) at any individual receptor as the TBM passes by.

9.2.4 The excavated material cut away by the TBM is carried to the surface either by conveyors or pipe-work. Experience from other tunnelling projects such as the Channel Tunnel Rail Link (London tunnels) and Jubilee line extension, has demonstrated that neither of these conveyance methods generate significant groundborne noise or vibration outside of the tunnel.

Temporary construction railway (TCR)

9.2.5 Materials (including tunnel lining segments), people and equipment are transported from the surface to the TBM using a TCR. The TCR can also be used to transport excavated material from the TBMs to the surface. This TCR can generate groundborne noise and vibration in the same way as a permanent railway.

9.2.6 Track would be laid behind the TBM as it progresses from the tunnel drive site, and would include sections of double track where two construction trains could pass in the tunnel.

9.2.7 Experience from other tunnelling projects (see para. 9.2.4) has demonstrated that groundborne noise and vibration levels from TCRs are less than those associated with the operation of the TBMs.

Code of Construction Practice

9.2.8 Generic measures incorporated into the *CoCP Part A* Section 6.4 to reduce noise and vibration from the operation of the TCR include: the alignment, jointing and mounting of the temporary construction railway would be installed, maintained and operated in a manner so as to minimise the transmission of vibration and groundborne noise from the passage of rail vehicles. Track passing locations (including joints and switches) would be located away from sensitive surface receptors. In addition, speed restrictions may also be required.

9.2.9 In addition, all diesel locomotives used would be fitted with efficient exhaust silencers.

9.3 Assessment methodology

9.3.1 The methodology for preparing the project-wide assessment is described in Volume 2 Environmental assessment methodology Section 9. Engagement and methodological assumptions and limitations of specific relevance to the project-wide assessment are detailed below.

Engagement

9.3.2 Vol 3 Table 9.3.1 presents specific comments from consultees in relation to noise and vibration raised at scoping or other consultation stages, and the responses.

Vol 3 Table 9.3.1 Noise and vibration – consultation comments and responses

Organisation	Comment	Response
Marine Management Organisation, phase two consultation response, February 2012	The long term sub riverbed noise from the tunnel boring machine ('TBM') may have an impact on any spawning/nursery or migratory fish species, however this does not appear to have been	The TBM is a transient source moving at 10-15m per day. It is considered unlikely that effects would be experienced over a period of time long enough to affect spawning/nursery activities. This is considered further in Section 5 of this volume.

Organisation	Comment	Response
	considered in the PIER[iv].	
London Borough (LB) of Southwark, phase two consultation response, February 2012	It is not clear why there is a change in the contours in the vicinity of Tower Bridge in connection with the predicted vibration levels in Vol 6 Figure 5.4.18 TBM Ground borne noise contours.	Shortly after passing under Tower Bridge the TBM moves from operating in Thanet Sands to chalk. The level of groundborne noise transmitted to the surface is highly dependent on the medium in which it is transmitted, and so the change in ground composition results in the change in contour at this location.
LB of Southwark, phase two consultation response, February 2012	In respect of "Vol 6 Table 5.4.4. Ground borne noise impacts from TCR" table, there is no assessment to the duration of the low impact (35 — 39 dB (A)) that the 310 residential properties. A significant period of a low impact will cause a significant impact.	An approximate duration of low impact has been added to this assessment. The duration is limited but dependant on the rate of progression of the TBM
LB of Southwark, phase two consultation response, February 2012	Also the cumulative effect of the TBM and TCR has [not] been considered in the report.	There are a number of reasons why a cumulative assessment is not valid in this context: • The TBM support gantries are typically over 100m long and therefore the cutting face and temporary construction railway would always be at least 100m apart. • The predicted TCR groundborne noise level is based upon an assumed

[iv] The EIA process has progressed considerably since the publication of *the Preliminary environmental information report* and the *PEIR* has effectively been superseded by this *Environmental Statement*. The *PEIR* is nevertheless available on the Thames Tideway Tunnel consultation website

Organisation	Comment	Response
		maximum line speed of 15km/h train speed. When the supply trains reach the TBM they would necessarily be going much slower than this, therefore the groundborne noise and vibration level would be considerably reduced compared to the maximum line speed. • The TBM is a transient source and therefore the cumulative level would only be applicable for a few days.
LB of Southwark, phase two consultation response, February 2012	In the plan showing the Greenwich Tunnel TCR groundborne noise levels (Vol. 6 Figure 5.4.22), there is no upper limit shown for the groundborne noise contours. It is presumed from the text that the upper limit is 40dB, but this should be shown on the legend for the plan.	Plan legend has been amended in Vol 3 Figures 9.5.12 to 9.5.22 (see separate volume of figures)
St. Thomas's Hospital, Westminster Bridge Road, SE1 7HY	St Thomas's Hospital responded to notice letter issued requesting information on any particularly vibration sensitive processes.	A meeting to discuss the potentially vibration sensitive equipment identified was held in February 2012. It is likely that the area of the hospital were this equipment is located is more than 250m from the main tunnel and is already isolated to protect from vibration sources.
London Bridge Hospital, 27 Tooley Street, SE1 2PR	A letter requesting information on any particularly vibration sensitive processes has been issued.	A response had not been received at the time of the assessment.
Imperial College	As a major acute teaching hospital trust	A review of the site plans

Organisation	Comment	Response
Healthcare NHS Trust (Charing Cross Hospital, Fulham Palace Road, W6 8RF)	we have many and various items of equipment which would be highly sensitive to both vibration and electrical interference. [Attached to the response was a plan of the Trust's hospitals including Charing Cross Hospital which is the closest to the Thames Tideway Tunnel construction works.] The equipment which would be affected is spread across and throughout the sites.	has been undertaken. The short connection tunnel at Hammersmith is approximately 230m from the closest building in the Charing Cross hospital site, which is the Pilot Building. All other buildings are more than 250m from the tunnel works.
The Lister Hospital, Chelsea Bridge Road, SW1W 8RH	Letter requesting information on any particularly vibration sensitive processes has been issued.	A response had not been received at the time of the assessment.
Bureau of Forensic Science Ltd, 3-7 Temple Avenue. EC4Y 0HP	Letter requesting information on any particularly vibration sensitive processes has been issued.	A response had not been received at the time of the assessment.
Surrey Quays Veterinary surgery, 156 Lower Road, SE16 2UG	Letter requesting information on any particularly vibration sensitive processes has been issued.	A response had not been received at the time of the assessment.
Ministry Of Defence buildings, Horseguards Avenue, SW1A and Albert Embankment, SE1	Letter requesting information on any particularly vibration sensitive processes has been issued.	A response had not been received at the time of the assessment.
Image Diagnostic	Letter requesting information on any	A response had not been received at the time of the

Organisation	Comment	Response
Technology Ltd, 36 Warple Way, W3 0RG.	particularly vibration sensitive processes has been issued.	assessment.
Panorama Antennas, Frogmore, SW18 1HF	At our Frogmore premises we have equipment including but not limited to RF test equipment, production machinery, computer hardware and delicate calibrated test and measurement equipment which may be vulnerable to the factors you describe.	Whilst some of the items identified are not considered to be very vibration sensitive, the "delicate calibrated test and measurement equipment" has the potential to be very vibration sensitive.

Assumptions and limitations

Assumptions

9.3.3 The generic assumptions and limitations associated with this assessment are presented in Vol 2 Section 9. The site-specific assumptions are as follows:

a. The assessment uses the upper band data for the specific ground type which the tunnel is operating. This is considered to be a worst-case assessment at this stage, as it uses a hypothetical analysis based on conservative data from TRL Report 429 (Hiller and Crabb, 2000)[1] since data for a project of this scale are unavailable at this time. This is considered robust, as the methodology is based on empirical data from a large number of other UK tunnelling projects, including the Channel Tunnel TBM.

b. The construction equipment assumed within the assessment is based on consideration of the size of the tunnel. For example, the TBM required to construct the main tunnel would be larger than that required to construct the short connection tunnels and this has been taken into account in the assessment. The impacts are assessed on an average tunnelling rate of 90m per week.

c. The assessment assumes two trains operating on the temporary construction railway an hour in each direction for the main tunnel, and the Frogmore and Greenwich long connection tunnels.

d. The assessment assumes that the main tunnel and the Greenwich long connection tunnel would operate a 900mm gauge construction railway with a loco with a mass of approximately 15 tonnes per axle. It is assumed that the Frogmore long connection tunnel and the Falconbrook and Hammersmith short connection tunnels would operate a 600mm gauge construction railway with a loco with a mass of approximately 6 tonnes per axle.

e. The *CoCP Part A* Section 6.4 states that the TCR would be installed, maintained and operated in a manner so as to minimise the transmission of vibration and groundborne noise from the passage of rail vehicles. Based on this, the assessment has assumed that the joints of the TCR would achieve a variation in rail height which is commensurate with the system being maintained at this high level.

f. The *CoCP Part A* Section 6.4 states that TCR speed restrictions may also be required under sensitive surface receptors. It is assumed for the purpose of the assessment that the construction trains operating on the TCR would not exceed a speed limit of 15km/h. Based on experience from other tunnelling projects, this is considered a reasonable track speed for a TCR of the type proposed.

Limitations

9.3.4 The assessment is based upon the upper band data for the specific ground type from TRL 429. Data from the Lee Tunnel would be collected when construction of the tunnel commences and this would be used to inform operating guidelines for the Thames Tideway Tunnel project. In addition to this project data, the operating guidelines would be developed based on the contractor's equipment and construction sequence.

9.3.5 Responses have not yet been received from all the very vibration sensitive receptors however the assessment has been undertaken using the best available information and professional experience.

9.3.6 Despite the limitations above, the assessment is considered robust.

9.4 Baseline conditions

Current baseline

9.4.1 The current groundborne noise and vibration baseline at the vast majority of the receptors along the route is effectively negligible. This is because groundborne noise and vibration is typically only generated within receptors adjacent to an underground railway, or certain types of industrial activities, and these sources only affect a small number of receptors along the route.

9.4.2 Given that the majority of the receptors are not subject to appreciable existing levels of groundborne noise or vibration, the assessment is based upon an absolute criterion rather than change criteria.

9.4.3 At those receptors where there is an existing appreciable level of groundborne noise or vibration, the absolute assessment is considered more robust than a change criteria assessment.

9.4.4 Given that the assessment is based upon absolute criteria there is no need to determine the baseline level of groundborne noise or vibration and hence baseline measurements have not been undertaken for the project-wide assessment.

9.4.5 All residential receptors within 65m[v] of the tunnel alignment have been considered within the assessment. The maximum assessment distance takes into consideration the assessment criteria, the ground conditions likely to result in the highest levels of groundborne noise and vibration and potential types of residence foundations.

9.4.6 Non-residential receptors including hospitals, recording studios, schools, churches, offices and doctors' surgeries have been included within the assessment and the assessment distance for these receptors is 100mv. The scoping distance is greater than for residential properties as certain non-residential building uses, for example TV or recording studios, are considered to be more sensitive to noise than residential premises. The maximum assessment distance takes into consideration the assessment criteria, the ground conditions likely to result in the highest levels of groundborne noise and vibration and potential types of building foundations.

9.4.7 Whilst they are rare within metropolitan areas, all non-residential receptors which are potentially particularly sensitive to vibration within 250m of the alignment have been identified. These include surgical facilities, university laboratories, private laboratories, nanotechnology facilities and specialist manufacturers.

9.4.8 The following potential non-residential receptors which are considered very sensitive to vibration have been identified through this process and have been contacted in order to determine if they have equipment or processes which are particularly sensitive to vibration:

a. St. Thomas's Hospital
b. London Bridge Hospital
c. Charing Cross Hospital
d. The Lister Hospital
e. Bureau of Forensic Science Ltd
f. Surrey Quays Veterinary surgery
g. Ministry of Defence buildings (including Vauxhall Cross)
h. Image Diagnostic Technology Ltd.
i. Panorama Antennas.

9.4.9 It is understood that a further very vibration sensitive receptor (Digital TV Group) is located in the basement of Camelford House, however no further information was available at the time of the assessment.

9.4.10 Responses from receptors who consider that they operate equipment which is very sensitive to vibration have been reviewed against the predicted incident vibration levels, the operational requirements for the equipment, hours of operation and the envisaged progress of the TBM, and potential significant effects have been identified on a case-by-case

[v] Measured horizontally on plan from the tunnel centreline

basis. For those receptors who did not respond to consultation or for whom further information was not available, the assessment has been undertaken using professional judgement.

9.4.11 In the majority of instances given the distance from the tunnel alignment and the proximity of other vibration sources, including major roads, underground railways, overground railways and sources within the buildings themselves (lifts, etc), mitigation would already be applied to the sensitive equipment to control vibration from these sources. This would be sufficient to control the incident vibration resulting from the operation of the TBM.

Construction base case

9.4.12 None of the schemes outlined in the project-wide development schedule (Vol 3 Appendix A.1) are considered relevant to the project-wide assessment base case, as they are either under construction during Project Year 1 or none of them would introduce sensitive receptors that are closer to the construction works than those already considered below.

9.4.13 The developments specified as being completed before the commencement of construction in the site-specific development schedules (Appendix N of Vols 4 to 27) have been considered in the assessment where they constitute a sensitive receptor and fall within the assessment area. Those developments that are relevant to the project-wide base case have been assessed with reference to the assessment contours presented in Vol 3 Figures 9.5.1 to 9.5.44 (see separate volume of figures).

9.4.14 Of the schemes outlined in the project-wide development schedule (Vol 3 Appendix A.1) Crossrail and the Northern Line Extension (NLE) are considered relevant to the construction cumulative assessment as they are assumed to be under construction at the same time as the Thames Tideway Tunnel project and would involve tunnelling activities.

9.4.15 The remaining developments in Vol 3 Appendix A.1 are not considered relevant to the construction cumulative assessment because although under construction at the same time as Thames Tideway Tunnel project they would not involve tunnelling activities and would therefore not contribute to groundborne noise and vibration at a project wide level.

9.4.16 No site-specific developments are considered relevant to the project-wide cumulative assessment as none of them involve tunnelling activities and would therefore not contribute to groundborne noise and vibration at a project wide level.

9.5 Construction effects assessment

Groundborne noise

TBMs

9.5.1 Groundborne noise contours from the operation of the TBMs are presented in:

a. Main tunnel – Acton Storm Tanks to Abbey Mills Pumping Station, and short connection tunnels at Hammersmith Pumping Station and Falconbrook Pumping Station – Vol 3 Figure 9.5.1 to Vol 3 Figure 9.5.9 (see separate volume of figures)

b. Frogmore long connection tunnel - Vol 3 Figure 9.5.10 (see separate volume of figures)

c. Greenwich long connection Tunnel - Vol 3 Figure 9.5.11 (see separate volume of figures)

Impacts on residential receptors

9.5.2 The contours in Vol 3 Figure 9.5.1 to Vol 3 Figure 9.5.11 (see separate volume of figures) have been used along with GIS address data (address-point) to identify the number of residences which fall into the groundborne noise impact categories defined in Vol 2 Section 9. The number of residential properties in each category of groundborne noise exposure is presented in Vol 3 Table 9.5.1.

Vol 3 Table 9.5.1 Noise – groundborne impacts from TBMs at residential receptors

Route	Number of residential properties predicted to experience the groundborne noise levels below, $dBL_{Amax, slow}$ (Rounded to the nearest 5)			
		Significant Impact		
	Low 35-39	Medium 40-44	High 45-49	Very High >49
Main tunnel	290	175	0	0
Frogmore long connection tunnel	5	5	180	0
Greenwich long connection tunnel	0	0	0	0
Hammersmith Short connection tunnel	120	0	0	0
Falconbrook short connection tunnel	0	0	0	0
Total	415	180	180	0

9.5.3 A medium and high groundborne noise impact from the operation of the TBM is predicted at residential properties adjacent to the route between Acton Storm Tanks and the River Thames and above the Frogmore long connection tunnel.

9.5.4 The groundborne noise impacts and approximate duration are summarised in Vol 3 Table 9.5.2.

Vol 3 Table 9.5.2 Noise – duration of groundborne noise impact from TBMs

Tunnel	Number of properties and duration of impact (days)		
	Medium	High	Very High
Main tunnel	175 properties / 3 days	0	0
Frogmore long connection tunnel	5 properties / 6 days	180 properties / 2 days	0
Greenwich long connection tunnel	0	0	0
Hammersmith short connection tunnel	0	0	0
Falconbrook short connection tunnel	0	0	0

9.5.5 Although the residences are considered to have high sensitivity to groundborne noise, a medium/high impact is not predicted to be experienced for more than six days at any residential receptor as the TBM passes the receptor.

9.5.6 The TBM groundborne noise is predicted to exceed the likely significant effect threshold level for groundborne noise, however when the magnitude of the impact is considered in combination with the duration of the impact, the effect would be insufficient to cause sustained disturbance to occupants. Based on professional judgement the overall effect (ie, the resulting disturbance to occupants in this case) would be rated as **not significant**.

Impacts on non-residential receptors

9.5.7 The assessment methodology for non-residential sensitive receptors differs to that for residential receptors (see Vol 2 Section 9.8). For non-residential sensitive receptors the predicted groundborne noise levels and the likely significant effect thresholds presented in Vol 2 Section 9.8 have been compared. The impacted non-residential buildings are identified in Vol 3 Table 9.5.3.

Vol 3 Table 9.5.3 Noise – non - residential groundborne impacts from TBMs

Receptor	Sensitivity	Likely Significant Effect Threshold $dBL_{Amax, slow}$	Predicted Construction GBN level, $dBL_{Amax, slow}$	Duration (days)
Chiswick Seventh-day Adventist Church	High	35	40-44	4
St Paul's School[vi]	High	40	40-44	2
All Saints Church, Wandsworth	High	35	40-44	6
British Olympic Association, 1 Wandsworth Plain	Medium	40	45-49	6
119 Wandsworth High Street (office)	Medium	40	40-44	6
Eagle Rock Entertainment, 22 Armoury Way (office)	Medium	40	40-44	6
Frogmore Complex offices, Dormay Street	Medium	40	40-44	6
Panorama Antennas UK Ltd, 61 Frogmore	Medium	40	40-44	6
Office, 86 Wandsworth High Street	Medium	40	40-44	6

9.5.8 Although the receptors are considered to have medium/high sensitivity to groundborne noise, an impact is not predicted to be experienced for more than six days at any receptor.

9.5.9 The TBM noise is predicted to exceed the impact noise level threshold, however, the duration of the impact would be insufficient to cause sustained disturbance to occupants. Hence the overall effect (ie, the

[vi] The assessment has assumed that the school buildings are constructed with piled foundations. If the school buildings are not constructed on piled foundation then no impact would be identified.

resulting disturbance to occupants in this case) would be considered to be **not significant**.

Temporary construction railway

9.5.10 The results of the assessment of groundborne noise from the operation of the TCR are presented in Vol 3 Table 9.5.4 and Vol 3 Table 9.5.5.

9.5.11 Groundborne vibration contours from the operation of the TCR are presented in:

a. main tunnel – Acton Storm Tanks to Abbey Mills Pumping Station - Vol 3 Figure 9.5.12 to Vol 3 Figure 9.5.20 (see separate volume of figures)

b. Frogmore long connection tunnel - Vol 3 Figure 9.5.21 (see separate volume of figures)

c. Greenwich long connection Tunnel - Vol 3 Figure 9.5.22 (see separate volume of figures).

Impacts on residential receptors

9.5.12 The contours in Vol 3 Figure 9.5.12 to Vol 3 Figure 9.5.22 (see separate volume of figures) have been used along with GIS address data (address-point) to identify the number of residences which fall into the groundborne noise impact categories defined in Vol 2 Section 9. The residential properties in each category of groundborne noise exposure are presented in Vol 3 Table 9.5.4.

Vol 3 Table 9.5.4 Noise – residential groundborne noise impacts from the TCR

Route	Number of residential properties predicted to experience the groundborne noise levels below, $dBL_{Amax, slow}$ (Rounded to the nearest 5)			
		Significant Impact		
	Low 35-39	Medium 40-44	High 45-49	Very High >49
Main tunnel	90	0	0	0
Frogmore long connection tunnel	5	0	0	0
Greenwich long connection tunnel	0	0	0	0
Hammersmith short connection tunnel	0	0	0	0
Falconbrook short connection tunnel	0	0	0	0
Total	95	0	0	0

9.5.13 'Low' groundborne noise impacts from the operation of the TCR are predicted at residential properties adjacent to the route near to Acton Storm Tanks at the end of the drive and above the Frogmore connection tunnel.

9.5.14 The approximate duration of the 'Low' groundborne noise impacts is as follows:

a. Frogmore connection tunnel (section from Dormay Street to King George's Park) – three months (two months during the tunnel construction and 1 month during the tunnel lining)

b. Main tunnel (section from river to Acton Storm Tanks) – up to 12 months (five months during the tunnel construction and seven months during tunnel lining).

9.5.15 The impacts identified in Vol 3 Table 9.5.4 all fall within the 'Low' impact category, which whilst potentially audible is unlikely to result in complaint. The impact category is determined by the maximum level which occurs as each train travels beneath the receptor.

9.5.16 During the most intensive periods two TCR train movements have been assumed each hour. The pass-by duration would be typically less than 30 seconds and the maximum noise level would only be achieved during a proportion of this period..

9.5.17 Considering the magnitude of the impact, the number and duration of events, the sensitivity of the receptors and the duration of the impact, it is considered that groundborne noise from the TCR at these residences is **not significant**.

Impacts on non-residential receptors

9.5.18 For non-residential sensitive receptors, the predicted groundborne noise levels and the impact thresholds presented in Vol 2 Section 9.8 have been compared. The impacted non-residential buildings are identified in Vol 3 Table 9.5.5.

Vol 3 Table 9.5.5 Noise – non - residential groundborne noise impacts from TCR

Receptor	Sensitivity	Impact Threshold $dBL_{Amax, slow}$	Predicted Construction GBN level, $dBL_{Amax, slow}$	Duration (months)
Chiswick Seventh-day Adventist Church	High	35	35-39	5

9.5.19 The significant impact threshold is predicted to be exceeded for five months at Chiswick Seventh-day Adventist Church, which whilst potentially audible is unlikely to result in complaint.

9.5.20 During the most intensive periods two TCR train movements have been assumed each hour. The pass-by duration would be typically less than 30 seconds and the maximum noise level would only be achieved during a proportion of this period.

9.5.21 Considering the number and duration of events which result in this level, and the magnitude of the impact above the threshold value, it is considered that the impact would not be sufficient to cause disturbance to the occupants and therefore the effect is considered to be **not significant**.

Groundborne vibration

9.5.22 The assessment of construction vibration considers events which have the potential to result in human response to vibration and also in damage to buildings or structures. These are considered separately using different parameters as set out in Vol 2 Section 9.8.

Groundborne vibration - human response assessment

9.5.23 The assessment of potential construction vibration impacts that could result in a human response at neighbouring receptors has been assessed using the predicted Vibration Dose Value (VDV).

Tunnel boring machine – daytime

9.5.24 The results of the assessment of groundborne vibration from the operation of the TBM are presented in Vol 3 Table 9.5.6.

9.5.25 Groundborne vibration contours from the operation of the TBMs are presented in:

a. Main tunnel – Acton Storm Tanks to Abbey Mills Pumping Station, and short connection tunnels at Hammersmith Pumping Station and Falconbrook Pumping Station - Vol 3 Figure 9.5.23 to Vol 3 Figure 9.5.31 (see separate volume of figures)

b. Frogmore long connection tunnel - Vol 3 Figure 9.5.32 (see separate volume of figures)

c. Greenwich long connection Tunnel - Vol 3 Figure 9.5.33 (see separate volume of figures).

9.5.26 The contours in Vol 3 Figure 9.5.23 to Vol 3 Figure 9.5.33 (see separate volume of figures) have been used along with GIS address data (address-point) to identify the number of residences which fall into the groundborne vibration categories defined in Vol 2 Section 9. The number of residential properties in each category of groundborne vibration exposure presented in Vol 3 Table 9.5.6.

Vol 3 Table 9.5.6 Vibration – from TBMs at residential receptors (daytime)

Route	Number of residential properties predicted to experience the VDV during the daytime, $mms^{-1.75}$ (rounded to the nearest 5)		
	Low probability of adverse comment 0.2-0.4	**Adverse comment possible 0.4-0.8**	**Adverse comment probable 0.8-1.6**
Main tunnel	1450	0	0
Frogmore long connection tunnel	0	0	0
Greenwich long connection tunnel	2000	0	0
Hammersmith Short connection tunnel	0	0	0
Falconbrook short connection tunnel	0	0	0
Total	3450	0	0

9.5.27 The predicted VDVs at all receptors during the daytime fall within or below the 'Low probability of adverse comment' band, as described in Vol 2 Section 9 and therefore significant effects are not anticipated at these locations.

Tunnel boring machine – night-time

9.5.28 The results of the assessment of groundborne vibration from the operation of the TBM are presented in Vol 3 Table 9.5.7.

9.5.29 Groundborne vibration contours from the operation of the TBMs are presented in:

a. Main tunnel – Acton Storm Tanks to Abbey Mills Pumping Station, and short connection tunnels at Hammersmith Pumping Station and Falconbrook Pumping Station - Vol 3 Figure 9.5.34 to Vol 3 Figure 9.5.42 (see separate volume of figures)

b. Frogmore long connection tunnel - Vol 3 Figure 9.5.43 (see separate volume of figures)

c. Greenwich long connection tunnel - Vol 3 Figure 9.5.44 (see separate volume of figures).

9.5.30 The contours in Vol 3 Figure 9.5.34 to Vol 3 Figure 9.5.44 (see separate volume of figures) have been used along with GIS address data (address-point) to identify the number of residences which fall into the groundborne vibration impact categories defined in Vol 2 Section 9. The number of residential properties in each category of groundborne vibration exposure is presented in Vol 3 Table 9.5.7.

Vol 3 Table 9.5.7 Vibration – from TBMs at residential receptors (night time)

Route	Number of residential properties predicted to experience the VDV during the night time, $mms^{-1.75}$ (rounded to the nearest 5)		
	Low probability of adverse comment 0.1-0.2	Adverse comment possible 0.2-0.4	Adverse comment probable 0.4-0.8
Main tunnel	4000	0	0
Frogmore connection tunnel	180	0	0
Greenwich connection tunnel	2100	350	0
Hammersmith Short connection tunnel	200	0	0
Falconbrook short connection tunnel	0	0	0
Total	6480	350	0

9.5.31 The predicted night-time VDVs at the majority of receptors fall within or below the ‘Low probability of adverse comment’ band, as described in Vol 2 Section 9 and therefore significant effects are not anticipated at these locations.

9.5.32 The predicted night time VDVs at 350 residential receptors fall within the ‘Adverse Comment Possible’ band, as described in Vol 2 Section 9. The duration for which residences would be subject to this value is predicted to be less than one week. Given the short duration, vibration is considered to be **not significant** at these locations.

Temporary construction railway – daytime and night-time

9.5.33 The assessment of groundborne vibration from the operation of the TCRs in the main, Frogmore and Greenwich long connection tunnels does not predict any vibration greater than 0.2VDVms$^{-1.75}$ during the daytime or 0.1VDVms$^{-1.75}$ during the night-time. This means that impacts are below the threshold of 'Low probability of adverse comment' and therefore no groundborne vibration effects are identified from the operation of the TCR.

Groundborne vibration (building damage)

9.5.34 The assessment of potential construction vibration impacts at adjacent buildings / structures has also been assessed using the predicted Peak Particle Velocity (PPV) as described in Vol 2 Section 9. Separate thresholds are presented for transient and continuous vibration. For this assessment both the operation of the TBMs and TCR have been assessed against the more onerous continuous vibration criteria.

Tunnel boring machine

9.5.35 The assessment of groundborne vibration from the operation of the TBM does not predict a PPV greater than the building damage impact criteria specified in Vol 2 Section 9.5, at any receptor along the route, and therefore no building damage construction vibration effects are identified from this source.

Temporary construction railway

9.5.36 The assessment of groundborne vibration from the operation of the TCR does not predict a PPV greater than the building damage impact criteria specified in Vol 2 Section 9.5, at any receptor along the route, and therefore no building damage construction vibration impacts or effects are identified from this source.

Groundborne Vibration (very vibration sensitive receptors)

9.5.37 The assessment of vibration at receptors which are considered very sensitive to vibration has been undertaken on an individual receptor basis. At the time of completing the assessment, responses had not been received from all the receptors however the assessment has been undertaken using a precautionary approach with the best available information and professional experience.

9.5.38 Responses have been received from St. Thomas' Hospital, Imperial College Healthcare Trust and Panorama Antennas. The 'very vibration sensitive' equipment at St Thomas' Hospital is located away from the river (and the route of the Thames Tideway Tunnel project) and therefore impacts are considered unlikely. Given the proximity of the Pilot Building at Charing Cross Hospital to Charing Cross Road, an impact is also considered unlikely as very vibration sensitive equipment would likely to already require mitigation from road traffic vibration.

9.5.39 At these hospitals, the likelihood of impact during the operation of the TBM is low given the location of other intervening vibration sources and the distance between the buildings and the tunnelling works, therefore vibration effects are considered to be **not significant** at these receptors.

9.5.40 At Panorama Antennas, the building is located above the alignment of the Frogmore connection tunnel and there remains potential risk that an impact could be identified at their calibrated test and measurement equipment, and therefore vibration is considered to be potentially **significant** at this receptor.

9.5.41 For the following receptors a response had not been received at the time of completing the assessment:

a. London Bridge Hospital

b. The Lister Hospital

c. Bureau of Forensic Science Ltd

d. Surrey Quays veterinary surgery

e. Ministry Of Defence buildings

f. Image Diagnostic Technology Ltd.

g. Digital TV group

9.5.42 The likelihood of impact at these receptors during the operation of the TBM is low given that in the vast majority of situations this very sensitive equipment would already be protected against existing vibration sources, for example nearby road or even footfall vibration within a building. In the absence of any responses, it is assumed that where very vibration equipment is used, it is mitigated within the building. However a precautionary approach has been taken and as such vibration effects are considered to be **significant** in the absence of further information on these receptors.

9.6 Operational effects assessment

9.6.1 As described in para. 9.1.7, operational effects have not been assessed.

9.7 Cumulative effects assessment

Construction effects

9.7.1 Of the schemes outlined in the project-wide development schedule (Vol 3 Appendix A.1), Crossrail and the Northern Line Extension (NLE) are considered relevant to the construction cumulative assessment as they are assumed to be under construction at the same time as the Thames Tideway Tunnel project and would involve tunnelling activities. However, for engineering and settlement reasons, tunnels are not bored over the same area at the same time, for instance, the HS1 twin tunnels through north London where started at different times to ensure that the cutting face for each tunnel was kept at least 1km apart during construction. Therefore for the same reasons it is unlikely that the tunnels associated with this project and Crossrail and Northern line extension would be constructed at the same time through the same area, and therefore no cumulative significant effects are identified.

9.7.2 The site-specific noise and vibration residual effects have been reviewed against those properties identified as being impacted by groundborne noise and vibration during the tunnel construction which has confirmed that there are no receptors that would experience both site-specific and project-wide effects..

9.8 Mitigation and compensation

Mitigation

9.8.1 The above assessment has predicted significant adverse groundborne vibration effects at Panorama Antennas which has particularly vibration sensitive equipment or processes. Effects at those receptors where a consultation response was not received, are also considered significant.

9.8.2 Mitigation to control noise and vibration has been included at the design stage to address those sources likely to cause effects. The *CoCP Part A* Section 6 states that Best Practicable Means (BPM) are to be demonstrated to minimise noise and vibration. Such BPM measures include:

a. the TCR would be installed, maintained and operated in a manner so as to minimise the transmission of vibration and groundborne noise from the passage of rail vehicles

b. speed restrictions may be required under sensitive surface receptors

9.8.3 The implementation of BPM measures, along with the other environmental design measures contained within the *CoCP* would ensure that the works are carried out in a way that minimises noise and vibration effects. As such there are no further practicable onsite mitigation measures that can be adopted above those measures identified in the *CoCP*.

9.8.4 However due to the sensitivity of all the very vibration sensitive receptors considered in this assessment, Thames Water (TWUL)[vii] would ensure that dialogue is maintained with these very vibration sensitive receptors in order to further review the location and nature of their sensitive equipment to minimise significant effects on their activities.

9.8.5 TWUL would also ensure all identified potentially vibration sensitive receptors are contacted again in line with the communications and community/stakeholder liaison section of the *CoCP Part A* (Section 3) prior to construction, to ensure the construction phase is planned to minimise effects on sensitive equipment.

Compensation

9.8.6 A compensation programme relating to construction disturbance which may give rise to financial loss or damage to property has been established (see Schedule 2 of the *Statement of Reasons*, which accompanies this

[vii] Thames Water Utilities Ltd (TWUL). The *Draft Thames Water Utilities Limited (Thames Tideway Tunnel) Development Consent Order (Draft DCO)* contains an ability for TWUL to transfer powers to an Infrastructure Provider (as defined in article 2(1) of the *Draft DCO*) and/or, with the consent of the Secretary of State, another body

application). The programme has been established to address claims of exceptional hardship or disturbance from construction activities. The programme seeks to offset significant adverse construction phase effects where a receptor is identified to be eligible for compensation. The programme measures are not considered to be mitigation as there is no guarantee that the property in question would be eligible for compensation or that the compensation would be accepted by the affected party. The residual effects reported in this *Environmental Statement* therefore do not take the offsetting effects of these measures into account.

Operation

9.8.7 As described in para. 9.1.7, operational effects have not been assessed.

9.9 Residual effects assessment

Construction effects

9.9.1 The construction noise effects would remain as presented in Section 9.5.

Operational effects

9.9.2 As described in para. 9.1.7, operational effects have not been assessed.

9.10 Project-wide effects assessment summary

Vol 3 Table 9.10.1 Noise and vibration – summary of construction assessment

Receptor	Effect	Significance of effect	Mitigation	Significance of residual effect	Compensation
Residential and non-residential	TBM Ground-borne noise	Not Significant	None	Not Significant	
Residential and non-residential	TCR Ground-borne noise	Not Significant	None	Not Significant	
Residential and non-residential	TBM Vibration	Not Significant	None	Not Significant	
Particularly vibration sensitive	TBM Vibration	Significant	No further onsite mitigation practicable	Significant	Significant, however properties may be eligible for compensation (see para.9.8.6)
Residential and non-residential	TCR Vibration	Not Significant	None	Not Significant	
Particularly vibration sensitive	TCR Vibration	Not Significant	None	Not Significant	

9.11 Summary of significant effects at all sites

9.11.1 Significant adverse noise and/or vibration effects (pre-mitigation) have been identified at 14 sites as a result of construction activities. These 14 sites also have significant adverse residual noise and/or vibration effects. This is because it cannot be guaranteed that the compensation measures identified for affected properties would be accepted by the property owners and therefore the residual effect assessments do not take the compensation measures into account. Vol 3 Table 9.11.1 provides a summary of the significant effects identified at individual sites across the project.

9.11.2 No further practicable on-site mitigation can be adopted above those measures identified in the *CoCP Parts A and B* (Section 6). A *Thames Tideway Tunnel noise insulation and temporary re-housing* policy has been established (see Schedule 2 of the *Statement of Reasons*, which accompanies this application). For those properties identified as being eligible, the policy seeks to offset the effects arising from disturbance and would be implemented where predicted or measured construction noise levels exceed published trigger levels. Whilst there is no guarantee that the noise control or other offsetting measures would be accepted by the affected party, the residual effects presented in the *Environmental Statement* Vols 4 to 27 and Vol 3 Table 9.11.1 take the offsetting effects of this policy into account.

9.11.3 Residential receptors that are not eligible under the *Thames Tideway Tunnel noise insulation and temporary re-housing* policy, could submit a claim under the *Thames Tideway Tunnel project compensation programme* (see Schedule 2 of the *Statement of Reasons*, which accompanies this application) which has been established to address claims of exceptional hardship or disturbance. As there is no guarantee that the affected parties would be eligible for this compensation or that the compensation would be accepted by the affected party, the residual effects at residential properties reported in the *Environmental Statement* Vols 4 to 27 and presented in Vol 3 Table 9.11.1 do not take the compensation programme into account.

9.11.4 No significant adverse noise and vibration effects are predicted during the operation of the Thames Tideway Tunnel project.

9.11.5 The effects presented in Vol 3 Table 9.11.1 below represent a summary of the site-specific effects presented in Vols 4 to 27, and do not constitute additional effects arising from the proposed development.

Vol 3 Table 9.11.1 Noise and vibration – summary of likely significant effects at all sites

Significance of effect	Receptor	Description of effect	Sites with significant effects (pre-mitigation)	Sites with significant residual effects
Construction - Adverse	Residential	Surface construction noise	Hammersmith Pumping Station (Fulham Reach Blocks B and F) (see Vol 5 Section 9)	Hammersmith Pumping Station (Fulham Reach Blocks B and F) (see Vol 5 Section 9)
			Barn Elms (Lancaster House) (see Vol 6 Section 9)	Barn Elms (Lancaster House) (see Vol 6 Section 9)
			Putney Embankment Foreshore (Star & Garter Mansions, 10 Ruvigny Gardens, and Putney Pier houseboats) (see Vol 7 Section 9)	Putney Embankment Foreshore (Star & Garter Mansions, 10 Ruvigny Gardens, and Putney Pier houseboats) (see Vol 7 Section 9)
			Kirtling Street (Nine Elms Pier Houseboats, Riverlight Blocks A, B and C, Battersea Power Station Blocks PS, O1, RS4 (see Vol 14 Section 9)	Kirtling Street (Nine Elms Pier Houseboats, Riverlight Blocks A, B and C, Battersea Power Station Blocks PS, O1, RS4 (see Vol 14 Section 9)
			Heathwall Pumping Station (Riverlight Block F) (see Vol 15 Section 9)	Heathwall Pumping Station (Riverlight Block F) (see Vol 15 Section 9)
			Cremorne Wharf Depot (Lots Road Power Station, Station House) (see Vol 13 Section 9)	Cremorne Wharf Depot (Lots Road Power Station, Station House) (see Vol 13 Section 9)
			Chambers Wharf (Luna House and Axis	Chambers Wharf (Luna House and Axis

Significance of effect	Receptor	Description of effect	Sites with significant effects (pre-mitigation)	Sites with significant residual effects
			Court) (see Vol 20 Section 9) King Edward Memorial Park Foreshore (Free Trade Wharf South) (see Vol 21 Section 9) Earl Pumping Station (1-39 Chilton Grove, 108-136 Chilton Grove, 52-62 Croft Street and Cannon Wharf block J) (see Vol 22 Section 9) Shad Thames (Tamarind Court [front], Coriander Court [Maguire Street and Gainsford Street facades]) (see Vol 19 Section 9) Minor works site Bekesbourne Street (John Scurr House) (see Vol 27 Section 9)	Court) (see Vol 20 Section 9) King Edward Memorial Park Foreshore (Free Trade Wharf South) (see Vol 21 Section 9) Earl Pumping Station (1-39 Chilton Grove, 108-136 Chilton Grove, 52-62 Croft Street and Cannon Wharf block J) (see Vol 22 Section 9) Shad Thames (Tamarind Court [front], Coriander Court [Maguire Street and Gainsford Street facades]) (see Vol 19 Section 9) Minor works site Bekesbourne Street (John Scurr House) (see Vol 27 Section 9)
	Restaurant	Surface construction noise	Victoria Embankment Foreshore (Tattershall Castle and Hispaniola) (see Vol 17 Section 9)	Victoria Embankment Foreshore (Tattershall Castle and Hispaniola) (see Vol 17 Section 9)
	Office	Surface construction noise	Albert Embankment Foreshore (Camelford House, Tintagel House and Vauxhall Cross) (see Vol 16 Section 9)	Albert Embankment Foreshore (Camelford House, Tintagel House and Vauxhall Cross) (see Vol 16 Section 9)

Significance of effect	Receptor	Description of effect	Sites with significant effects (pre-mitigation)	Sites with significant residual effects
	Educational	Surface construction noise	King Edward Memorial Park (Pier Head Prep School) (see Vol 21 Section 9) Deptford Church Street (St Joseph's School) (see Vol 23 Section 9)	King Edward Memorial Park (Pier Head Prep School) (see Vol 21 Section 9) Deptford Church Street (St Joseph's School) (see Vol 23 Section 9)
	Place of Worship	Surface construction noise	Deptford Church Street (St Paul's Church) (see Vol 23 Section 9)	Deptford Church Street (St Paul's Church) (see Vol 23 Section 9)
	Residential	Construction vibration	Albert Embankment Foreshore (1-146 Bridge House) (see Vol 16 Section 9) King Edward Memorial Park Foreshore (Free trade Wharf South) (see Vol 21 Section 9) Earl Pumping Station (Block J Cannon Wharf and 52-62 Croft Street) (see Vol 22 Section 9) Shad Thames (Tamarind Court [front and rear], Coriander Court [Maguire Street and Gainsford Street facades]), (see Vol 19 Section 9)	Albert Embankment Foreshore (1-146 Bridge House) (see Vol 16 Section 9) King Edward Memorial Park Foreshore (Free trade Wharf South) (see Vol 21 Section 9) Earl Pumping Station (Block J Cannon Wharf and 52-62 Croft Street) (see Vol 22 Section 9) Shad Thames (Tamarind Court [front and rear], Coriander Court [Maguire Street and Gainsford Street facades]), (see Vol 19 Section 9)
	Office	Construction vibration	Albert Embankment Foreshore (Camelford House and Vauxhall Cross) (see Vol 16 Section 9)	Albert Embankment Foreshore (Camelford House and Vauxhall Cross) (see Vol 16 Section 9)

Significance of effect	Receptor	Description of effect	Sites with significant effects (pre-mitigation)	Sites with significant residual effects
			Shad Thames (Clove Building), (see Vol 19 Section 9)	Shad Thames (Clove Building), (see Vol 19 Section 9)

References

[1] D M Hiller and G I Crabb. *Transport Research Laboratory report 429*: *Groundborne vibration caused by mechanised construction works*, (2000).

This page is intentionally blank

Thames Tideway Tunnel
Thames Water Utilities Limited

Application for Development Consent

Application Reference Number: WWO10001

Environmental Statement

Doc Ref: **6.2.03**

Volume 3: Project-wide effects assessment

Section 10: Socio-economics

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

Hard copy available in

Box **17** Folder **A**
January 2013

Thames Tideway Tunnel
Creating a cleaner, healthier River Thames

This page is intentionally blank

Thames Tideway Tunnel

Environmental Statement

Volume 3: Project-wide effects assessment

Section 10: Socio-economics

List of contents

Page number

List of tables

Page number

This page is intentionally blank

10 Socio-economics

10.1 Introduction

10.1.1 This section presents the findings of the assessment of the likely project-wide effects on socio-economics.

10.1.2 As described in Volume 2 Environmental assessment methodology Section 10, certain socio-economic effects of the project could materialise at a project-wide level and therefore require assessment at the Greater London and Thames Estuary geographic levels. Such effects relate to the following topics which are likely to occur during the construction and operation phases of the Thames Tideway Tunnel project:

a. Employment generation and skills

b. Stimulation of industry sectors

c. Recreation, leisure and tourism-related effects.

10.1.3 A summary of significant effects identified at the site-specific level across the project is provided in Section 10.11.

Context – strategic socio-economic benefits

10.1.4 This section summarises the key elements of relevant background studies into the Thames Tideway Tunnel project in order to set the context for this assessment of project wide socio-economic effects.

10.1.5 There have been a number of cost benefit assessments (CBAs) and studies that have quantified or described the strategic economic benefits of the proposed development. The primary purpose of these studies was to establish whether the proposed development would have a positive net present value (NPV). This was generally achieved by estimating the costs of development and comparing those costs to the benefits a cleaner river would bring to London. Relevant points from these studies are presented below:

a. The first CBA produced by the Thames Tideway Tunnel Project Working Group[i] in 2005 suggested that the project would have a positive NPV. The study did not attempt to quantify the non monetary benefits such as the value to London of a cleaner river (Thames Tideway Strategic Study, 2005)[1]. It did not estimate the likely number of jobs that would be created.

b. Several further CBAs undertaken by third party organisations on behalf of Thames Tideway Tunnel project built on the findings of the 2005 CBA and revised down the expected NPV (NERA for Thames Water, 2007)[2], (Defra, 2007)[3], (Jacob Babtie, 2006)[4]. They did not estimate the likely number of jobs that would be created. However,

[i] The working group included Thames Water, Environment Agency, OFWAT, Department for Environment, Food and Rural Affairs, Greater London Authority, Building Research Establishment, Hyder Consulting and Eftec Consultancy

they found that the Thames Tideway Tunnel project would have a positive NPV and that the project was justified.

c. In November 2011 the Department for Environment, Food and Rural Affairs (DEFRA) produced an assessment of the economic case for the proposed development entitled 'Creating a River Thames fit for our Future' (DEFRA, 2011)[5]. The key arguments it made were that the NPV was in the range of £3.0 to £5.1billion. The study suggested that the proposed development would generate employment, regeneration, reputational and environmental benefits to London's economy. It is also estimated that the proposed development would generate around 4,250 direct jobs (ie, full time equivalent or FTE) during the construction phase.

d. In March 2012 Thames Water published a paper that described the economic benefits of the proposed development entitled *'Why Does London's Economy Need the Thames Tunnel' (*Thames Water, 2012)[6]. This report was based on research and analysis undertaken by KPMG. The key findings of the report were that the proposed development would create up to approximately 9,350 direct and indirect FTE jobs in the UK at the height of construction, comprised of up to approximately 4,250 gross direct construction phase jobs and up to 5,100 indirect jobs. The construction phase and these additional jobs would also create a lasting legacy of skills for workers connected to the project.

10.2 Proposed development relevant to socio-economics

10.2.1 The proposed development is described in Section 3 of this volume, with further details of each site described in Section 3 of Vols 4 to 27. The elements of the proposed development relevant to socio-economics are set out below.

Construction

10.2.2 The proposed development consists of construction of a main tunnel, two long connection tunnels (known as Frogmore and Greenwich), several short connection tunnels, and 24 construction sites situated across 13 London local authorities. Each site has its own local characteristics, which are discussed in the site-specific assessments in Vols 4 to 27.

10.2.3 The proposed development would generate employment opportunities along the tunnel route and at the construction sites, as well as within downstream supply industries including the transportation and manufacturing sectors. The creation of employment would be accompanied by investment in training and skills development for the workforce required to construct the proposed development and transport materials to and from the proposed construction sites by river.

10.2.4 For the EIA it has been assumed that 90% of these materials would be transported by river. This allows for periods that the river is unavailable or material is unsuitable for river transport. On this basis, it is anticipated that there would be 5,390 barges visits to the proposed construction sites and 10,780 barge movements overall during the whole project; thereby resulting in an increased demand for barge operating services and the local freight by water sector.

10.2.5 The proposed construction sites would include four located within designated public open spaces and 11 located directly on the River Thames foreshore. This would result in the temporary take up of public open space and public open realm at these sites.

Code of Construction Practice

10.2.6 Measures incorporated into the *Code of Construction Practice* (*CoCP)*[ii] *Part A* to reduce socio-economic effects include:

a. Construction arrangements would serve to limit adverse impacts upon local communities, businesses and the environment so far as reasonably practicable (*CoCP* Part A Section 2).

b. All land, including highways, footpaths, public open spaces, river embankments/waterways, loading facilities or other land occupied temporarily would be made good to the satisfaction of Thames Water and the local authority where required. This would be in accordance with the *Ecology and landscape management plan* and the approved landscape design for the site (*CoCP* Part A Section 4).

c. The contractor will carry out the works in such a manner as to limit undue inconvenience to the public and other river users arising from increased barge movements, as far as is reasonably practicable, and that a *River transport management plan* would be produced which would include assessment of risks to recreational river users and consider the potential for mitigation measures that can be employed (*CoCP* Part A Section 5).

10.2.7 There are no elements of the *CoCP Part B* that are directly relevant to this project-wide effects assessment. Elements of the *CoCP* that are relevant to the site-specific context are set out in Section 10 of Vols 4 to 27.

Operation

10.2.8 The proposed development would generate a small number of permanent employment opportunities during the operation stage. This employment would be primarily related to maintenance of the completed infrastructure.

10.2.9 The installation of above ground structures, as described in Section 3 of this volume, would result in the creation of new areas of public amenity space or open space at eight sites, seven of which would be as a result of the extension of the existing river wall out into the River Thames[iii]. This would create new areas of public amenity space, usually in association

[ii] The *Code of Construction Practice (CoCP)* is provided in Vol 1 Appendix A. It contains general requirements (*Part A*), and site specific requirements for this site (*Part B*).

[iii] Relevant sites are Putney Embankment Foreshore, Carnwath Road Riverside, Chelsea Embankment Foreshore, Heathwall Pumping Station, Albert Embankment Foreshore, Victoria Embankment Foreshore, Blackfriars Bridge Foreshore and King Edward Memorial Park

with the existing Thames Path National Trail and Right of Way (Thames Path).

10.2.10 The project would also result in a cleaner River Thames which would potentially have an effect on users of the river, and in turn affect leisure and recreation opportunities and public health.

10.3 Assessment methodology

10.3.1 The methodology for preparing the project-wide assessment is described in Vol 2. Engagement and methodological assumptions and limitations of specific relevance to the project-wide assessment are detailed below.

Engagement

10.3.2 Vol 2 documents the overall engagement which has been undertaken in preparing the *Environmental Statement*. Specific comments relevant to the project-wide assessment of effects on socio-economics are presented in Vol 3 Table 10.3.1.

Vol 3 Table 10.3.1 Socio-economics – stakeholder engagement

Organisation	Comment	Response
National Institute for Health and Clinical Excellence, (NICE) June 2011	NICE suggest there is a need for more precise definition of public health impacts. Opportunities for health-related physical activity, mental health and general well-being would be relevant areas to consider.	Detailed assessment of public health benefits is made in the *Health Impact Assessment* (*HIA*) and the relevant areas of the *HIA* are referenced in this assessment.
Environment Agency, April 2011	It is considered that the use of foreshore sites is likely to lead to a number of detrimental effects in relation to flood risk management, biodiversity and recreation.	Consideration of the impact of the proposed development on recreational facilities has been covered within this socio-economic assessment, at site specific and project-wide levels, as appropriate.
Infrastructure Planning Commission (now Planning Inspectorate) - Section 51 Advice, June 2011	The types of jobs generated by the construction phase could be considered in the context of the available workforce in the area.	The types of jobs generated are considered in the context of the workforce of the area in this assessment.
London Borough (LB) of	The council welcomes the employment creation that the	A *Skills and Employment Strategy*

Organisation	Comment	Response
Wandsworth, February 2012	tunnel is expected to bring about and would welcome the opportunity to work with Thames Water to maximise this opportunity for the borough's residents	has been produced to accompany the application for development consent (the application). Discussions have been undertaken with the relevant local authorities to inform the development of the *Skills and Employment Strategy*.
London Councils, February 2012	London Councils welcome the statement that the tunnel is expected to directly create over 4,000 jobs. London boroughs will be looking for a clear strategy for maximising the employment of Londoners in the construction of the main tunnel and would welcome the opportunity to work closely with Thames Water on this issue. Ambitious targets should be set.	As above.
Greater London Authority (incl. Transport for London), February 2012.	In relation to the issue of employment, skills and training, it is important that Thames Water put in place a programme to train and employ Londoners, especially those seeking work, to undertake as many of these jobs as possible.	Further to the above response; Objective 3 of the *Skills and Employment Strategy* puts forward actions which would include measures to ensure that opportunities are accessible to disadvantaged or under-represented sections of the population including ex-offenders and the unemployed.

Baseline

10.3.3 The baseline methodology follows the methodology described in Vol 2. There are no specific variations for identifying baseline conditions for the project-wide assessment area.

Construction

10.3.4 The base case is the peak year of construction works. The assessment area is as set out in Vol 2 Section 10.8.

10.3.5 The assessment methodology for the construction phase follows that described in Vol 2.

10.3.6 Of the developments listed in the site development schedule (see Vol 3 Appendix A.1), one, the London Olympics Legacy Communities Scheme, has been considered relevant to the construction assessment base case. This Legacies Communities Scheme would be progressively completely over a period of 18 years from 2013 and would result in the creation of a major public open space (Queen Elizabeth Olympic Park) and associated paths and facilities along the River Lee navigation channels traversing the site. It is expected that this new public open space would be complete and operational (ie, open to public access) in the construction phase assessment year.

10.3.7 Of the development listed in the site development schedule (see Vol 3 Appendix A.1), the London Olympics Legacy Communities Scheme, one has been considered in the construction effects cumulative assessment. As described above, because the development would be progressively delivered over a period of 18 years commencing in 2013, the project would be under construction at the same time as the Thames Tideway Tunnel project in the peak construction year of 2019[iv]. As such, the project would be likely to lead to cumulative construction effects at the project wide level.

10.3.8 Of the other development listed in the site development schedule (see Vol 3 Appendix A.1), Crossrail, Thameslink and the North London (Electricity Line) Reinforcement Project are due to be completed by 2018 and so would not be under construction at the same time as the peak construction year of the Thames Tideway Tunnel project. However, as they are major projects and as the final years of the construction periods for these projects would be likely to overlap with the first years of the construction of the Thames Tideway Tunnel project, they are also considered in the construction phase cumulative assessment.

Operation

10.3.9 The base case is Year 1 of operation. The assessment area is as set out in Vol 2 Section 10.5.

10.3.10 The assessment methodology for the operation phase follows that described in Vol 2 Section 10.

10.3.11 Of the major projects listed in the site development schedule (see Vol Appendix A.1), there are none which would introduce new receptors into the operational base case; significantly alter circumstances for those

[iv] In previous reports related to the Proposed Development the peak construction year may differ. For example, *Why Does London's Economy Need the Thames Tunn*el reported 2018 as being the peak construction year. This is because the estimated construction programme has evolved since these reports were published.

receptors covered by the operational assessment; or give rise to cumulative effects.

Assumptions and limitations

10.3.12 The general assumptions and limitations associated with the project-wide assessment are presented in Vol 2 Section 10. Specific additional assumptions relevant to the project-wide assessment of socio-economic effects are provided below.

Assumptions

Employment

10.3.13 The estimates of indirect jobs created by the multiplier effect and factors such as leakage, displacement and deadweight are based on the following assumptions:

a. 'Leakage': Leakage effects are the benefits to those outside the impact area. Analysis carried out on Census 2001 data indicated that 13% of people working in Greater London live outside the area (Office for National Statistics, 2001[7]). This corresponds to a low leakage as set out by Homes and Communities Agency (HCA) Guidance (Homes and Communities Agency, 2008[8]).

b. 'Displacement': Displacement measures the extent to which the benefits of a project are offset by reductions of output or employment elsewhere. It is assumed that due to the flexibility of the labour market, and the fact that construction workers at the proposed development represent a relatively small proportion of the Greater London labour force, displacement impacts of the direct construction employment would be low. Also relevant is that there may be some modest displacement effects arising from amenity impacts on businesses near to the project. Taking these factors in to account and following the HCA Additionality Guide a 'ready reckoner' for low displacement is used of 25%. (There could also be displacement effects associated with reduced incomes of consumers net of the higher water charges raised to pay for the project but these are not covered as part of this assessment).

c. 'Deadweight': Deadweight represents the effects that would occur if the project did not go ahead. The deadweight should be deducted from the gross effects to provide the net additional effects of the project. Deadweight effects relevant to this assessment relate to the jobs at the proposed development sites that would be relocated as a result of the project and which therefore could potentially be lost. This is estimated based on the actual number of jobs located within the proposed development site areas, or, if this number is not known, by applying average employment densities (as set out in the HCA Employment Densities Guidance (Homes and Communities Agency, 2010)[9]) to the floorspace of the occupied premises. In order to represent the worst case scenario in this assessment we have used the higher job density figure from the HCA guidance for sites where the number of existing jobs is not known. As it is assumed that compensation would be available in accordance with the *Thames Tideway Tunnel project compensation programme* (see Schedule 2 of the *Statement of Reasons*, which accompanies the application), it is considered likely that most jobs would be relocated and retained on other sites. In order to take a reasonable worst case into account, the assessment has assumed that one-third of the jobs that are relocated could potentially be lost. This figure has been arrived at by using professional judgement as there is little research or best practice guidance available to estimate this proportion. The same HCA Additionality Guide assumptions on displacement, leakage and the multiplier effect as described above and below are applied to the deadweight estimate to provide a net deadweight figure. This is then subtracted from the net indirect employment to provide total net employment.

d. 'Multiplier Effect': In addition to the direct construction employment generated by the project itself there would be an increase in local employment arising from the indirect effects of the Thames Tideway Tunnel project construction activity. Employment growth would arise locally through manufacturing services and suppliers to the construction process (indirect or supply linkage multipliers). Additionally, part of the income of the construction workers and suppliers would be spent locally and more widely in Greater London, generating further employment (induced or income multipliers). Two multipliers are applicable to this assessment:

   i Multiplier effects applicable to the main construction activity. A multiplier of 2.19 (219%) (Scottish Executive, 2007[10]) was the figure applied to the context of the Thames Tideway Tunnel project and used by the '*Why Does London's Economy Need the Thames Tunnel?*' report (Thames Water, 2012)[11]. This assessment therefore uses the 2.19 multiplier figure as it is specific to the construction industry and is therefore deemed the most appropriate data to use[v] (L.E.K. Consultants, 2009)[12], (BIS, 2009)[13].

   ii For the other direct employment relating to barge operation, tunnel segment manufacturing and maintenance work in the operational phase and the estimate of deadweight jobs, the HCA Additionality Guide provides a ready reckoner for multipliers. Greater London is likely to have 'strong' supply linkages based on the scale of its economy. Therefore a general multiplier of 1.7 (170%) is determined from the HCA guidance to be the most appropriate

[v] There are other potential multipliers that could be used to estimate indirect jobs. For example, L.E.K consultants commissioned by the UK Contractors Group in 2009 produced an estimate of multipliers for the UK construction industry ranging from 2.09 for Type I (excluding induced impacts) to 2.84 for Type II (including induced impacts). The Department for Business Innovation and Skills (BIS) produced research into the use of additionality multipliers to justify public interventions in which they implied that the two primary sources of data that should be used were either the English Partnerships (EP) Additionality Guidance or the Scottish Government Input/Output tables. The EP guidance does not include construction industry specific multipliers.

measure of multiplier effects for the other direct employment and deadweight.

10.3.14 Assumptions are made about the likely current number of barge operating jobs and the scale of the freight by water market based on best available information.

Limitations

10.3.15 Employment numbers used to assess the effects of construction and operational employment are based on the best available information and best practice experience available at this stage. The estimation of the figures has employed professional judgement.

10.4 Baseline conditions

10.4.1 The following section sets out the baseline conditions as observed in 2011/2012 for socio-economics within the assessment area. Base case conditions are also described

Current baseline

Community profile

10.4.2 The following community profile examines the demographic characteristics of Greater London, consistent with the assessment area for this socio-economic assessment. It also has regard to the 13 Greater London boroughs within which construction sites would be located during the construction phase (hereafter referred to as the 13 boroughs).

10.4.3 Within the 13 boroughs the demographic profile is diverse. At one end of the spectrum, the LB of Newham experiences some of the highest rates of income deprivation and overall deprivation (both over three times as high as the Greater London average for the same Indices of Multiple Deprivation (IMD) measures [Department for Communities and Local Government, 2010][14]) in comparison with Greater London and has a significantly high proportion of Black and Minority ethnic (BME) residents. On average its residents also suffer from generally poorer health and lower life expectancy compared to Greater London overall. By contrast, residents of the LB of Richmond upon Thames and City of London experience low rates of deprivation, generally good health, low instances of death by major illnesses, and high life expectancy, and tend to be older and mostly of White ethnic background.

10.4.4 A community profile for Greater London in comparison with England is outlined in Vol 3 Appendix H.1. The following points provide a summary of the community profile and provide context for this socio-economic assessment:

a. The resident population of Greater London was approximately 7,172,091 at the time of the last census for which data is available[vi].

[vi] Census 2001. This type of data for the 2011 Census had not been released at the time of the assessment.

b. The proportion of residents aged under 16 years within Greater London (just over one in five) aligns with the England average (both 20.2%). Of the 13 boroughs, the City of London has the lowest proportion of under 16 year olds (9.4%) less than half the Greater London and England averages. By contrast the LB of Newham has the highest proportion of under 16 year olds (26.2%).

c. The proportion of over 65 year olds within Greater London (12.4%) is lower than the England average (15.9%). Of the 13 boroughs, the LB of Newham, LB of Lambeth and LB of Tower Hamlets have the lowest proportions of over 65 year olds (approximately 9% each).

d. The proportion of White residents within Greater London (71.2%) is lower than the England average (90.9%). The LB of Newham has the lowest proportion of White residents (39.4%), considerably lower than the LB of Richmond upon Thames where over 90% of residents are White.

e. Within Greater London and England Asian residents are the most populous minority group overall (12.1% and 4.6% respectively), followed closely by Black residents who account for 10.9% and 2.3% of the populations of Greater London and England respectively.

f. Of the 13 boroughs the LB of Ealing, the LB of Tower Hamlets and the LB of Newham have notably higher proportions of Asian residents than both Greater London and England (24.5%, 36.6% and 32.5% respectively). The boroughs with the highest proportion of Black residents are the LB of Lambeth (25.8%), the LB of Southwark (25.9%) and the LB of Newham (21.9%). These proportions are all considerably higher than the Greater London and England averages.

g. Within Greater London the proportion of residents suffering from a long term or limiting illness (15.5%) is lower than the England average (17.9%). The majority of the 13 boroughs experience a lower instance of long term or limiting illness in comparison with England wide levels overall. The exceptions are the LB of Tower Hamlets, the LB of Greenwich and the LB of Newham, each of which have levels broadly in line with the England average.

h. The majority of the 13 boroughs largely fell within the lowest or middle quintiles of adult obesity relative to other Greater London boroughs. By contrast, all of the 13 boroughs experienced high rates of child obesity; with all of the boroughs largely falling within the highest or second highest quintiles (ie, the highest being the worst) relative to other Greater London boroughs.

i. The incidence of income deprivation and overall deprivation within Greater London is slightly higher than the England average. Within the LB of Tower Hamlets and the LB of Newham the incidence of both income deprivation and overall deprivation is considerably higher than across Greater London and England. By contrast there is no recorded incidence of income deprivation or overall deprivation within the City of London and no recorded incidence of overall deprivation within the LB of Richmond upon Thames.

10.4.5 The above demographic profile suggests that Greater London has a slightly higher proportion of residents of work age relative to England and that Greater London residents are considerably more as well. Greater London also experiences lower levels of long term or limiting illness in comparison with England as a whole. The incidence of income deprivation and overall deprivation within Greater London is slightly higher than the England averages.

Economic profile

10.4.6 An economic profile is presented in Vol 3 Appendix H.2. The following points provide a summary of the profile and provide context for this socio-economic assessment:

a. Within the 13 boroughs there approximately 2.4 million jobs[vii] and 249,000 businesses[viii].

b. The three largest sectors as measured by employment within the 13 boroughs are: Wholesale and Retail Trade/Repair of Motor Vehicles and Motorcycles (14%); Professional, Scientific and Technical Activities (13%); and Accommodation and Food Service Activities (9%). By comparison, the three largest sectors as measured by employment within Greater London are: Wholesale and Retail Trade/Repair of Motor Vehicles and Motorcycles (16%); Professional, Scientific and Technical Activities (11%); and Administrative and Support Services Activities (8%).

c. The three largest sectors as measured by businesses at locations/units within the 13 boroughs are: Wholesale and Retail Trade/Repair of Motor Vehicles and Motorcycles (12%); Professional, Scientific and Technical Activities (11%); and Administrative and Support Service Activities (10%).

d. Businesses within the smallest size band (1 to 9 employees) account for the greatest proportion across the 13 boroughs (85%) and within Greater London as a whole (88%). There are a number of boroughs which have a greater proportion of smaller businesses (1 to 9 employees) than Greater London as a whole, such as the LB of Lewisham (92%), LB of Newham (92%), RB of Greenwich (91%), LB of Richmond (91%), LB of Ealing (90%), LB of Wandsworth (90%) and LB of Lambeth (89%). Conversely within the City of London there are many more businesses employing more than 50 employees (7%) than the average across all 13 boroughs and Greater London as a whole (both 2%).

e. There are approximately 12,600 Construction sector businesses and 89,000 Construction sector jobs across the 13 boroughs. A particularly high proportion of these Construction businesses are located in the City of Westminster (15%) and LB of Ealing (14%). Of

[vii] Employees data reflect a head count of workers on-site rather than Full Time Equivalent (FTE) jobs. While employee figures are mostly based on actual reported data, a proportion is based on modelled data.

[viii] This count relates to business 'locations' or 'units'; an enterprise may have a number of business locations / units. It includes private sector, public sector and voluntary sector / charitable entities.

the 13 boroughs, the City of Westminster and the LB of Ealing also account for the greatest proportion of Construction jobs (24% and 11% respectively).

f. Across the 13 boroughs there are approximately 7,100 Manufacturing businesses and approximately 69,600 Manufacturing jobs. Of the 13 boroughs, the City of Westminster and LB of Ealing have a highest proportion of Manufacturing sector businesses (15% and 12% respectively).

10.4.7 Within the 13 boroughs there are approximately 5,800 Transport and Storage sector businesses and 69,700 Transport and Storage sector jobs. Both the LB of Ealing and City of Westminster account for a high proportion of Transport and Storage sector businesses (14% and 12% respectively). The LB of Newham accounts for the greatest proportion of Transport and Storage sector jobs (16%) but only 8% of all Transport and Storage sector business locations.

Receptors

Workers

10.4.8 With regard to direct employment related impacts, the receptors are the following categories of workers that would be affected by the proposed development:

a. Construction workers

b. Manufacturing workers (manufacturing tunnel segments during the construction phase)

c. Barge and ship operating workers (transporting freight/materials during the construction phase)

d. Other services workers (maintaining the tunnel during the operational phase).

Existing workforce numbers

10.4.9 The specific baseline characteristics, in terms of employment levels for each of the above category of workers, are as follows:

a. Construction workers: The number of people employed in Greater London in 2012 in the construction industry has been estimated by the GLA to be approximately 227,000 (GLA, 2010)[15].

b. Manufacturing workers: The number of people employed in Greater London in 2012 in the manufacturing industry, of which tunnel segment manufacturing is a subsector, has been estimated by the GLA to be approximately 184,000.

c. Barge and ship operating workers: The number of people employed in Greater London in the barge and ship operation industry is estimated by the Port of London Authority (PLA) to be approximately 1,900 (PLA, 2009)[16]. According to the PLA there are currently 22 registered barge and cargo handling companies serving the Greater London area although the majority of these firms handle cargo for their own processes and are not available for private hire (PLA, 2011)[17].

Consultation with the Company of Watermen and Lightermen suggest that there are around 300 to 350 people with Boatmasters' Licences (BMLs) (Peter Brett Associates, 2012)[18]. This includes approximately 75 at commercial tug and barge operation companies and the remainder working at tourist and passenger boat operators. Approximately 100 boatmasters working at passenger and tourist boat companies have previous experience working on barges and tugs.

d. Other services workers: The number of people employed in Greater London in 2012 in the 'other services' industry sector, within which category Thames Tideway Tunnel project maintenance operators would fall once the proposed development is completed, was estimated by the GLA to be approximately 458,000 in 2012.

Existing skills levels of workers

10.4.10 Given the specialised nature of the Thames Tideway Tunnel project it is likely that investment in the skills levels of some of the workers involved in the proposed development would be necessary. This mainly relates to construction workers and barge operators.

10.4.11 According to a recent report on skills and resource capacity in the UK tunnelling construction sector published by Department for Business Innovation and Skills (BIS), there are sufficient skills at the current time to meet current demand for tunnelling projects (BIS, 2012)[19]. This assessment is of demand for skills with the workforce at the current time and does not take account of future demand for such skills that would be likely to arise in the assessment year (see para. 10.4.47 for further detail regarding the skill level of the construction workforce in the base case).

10.4.12 The baseline skills level of barge operating workers is considered to be adequate to meet the current demand. According to analysis of Boatmasters' Licences that include local knowledge endorsements gained through consultation with the Company of Waterman and Lightermen there are approximately 300 to 350 BMLs currently in use on the River Thames (Thames Water, 2012)[20]. However, the same consultation concluded that the additional demand generated by the proposed development and other expected future activity on the river would lead to a skills shortage after 2016 (see para. 10.4.51a for further detail). This is partly because the current BML takes a minimum of 2 years to complete and the current take up is low.

Receptor sensitivity of workers

10.4.13 The sensitivity of workers in the above mentioned sectors (see para. 10.4.8) is primarily dependent on the availability of alternative sources of employment and their capacity to experience a loss or gain of employment. Construction work and work in related downstream industries can be generated by both small and large scale projects, and workers in the construction, manufacturing, barge and ship operating and other services sectors generally have a range of opportunities available to them to obtain employment. However it is acknowledged that current unemployment rate in London is relatively high at 8.7% against a national average of 7.8% (Office for National Statistics, 2012)[21].

10.4.14 The value that workers derive from employment is an additional consideration for assessing sensitivity. It is considered that the benefits that accrue to an individual as a result of obtaining employment are considerable. For example regular employment can benefit individuals in terms of a regular wage, improved personal financial stability and improved personal health and wellbeing. It is also likely that both a proportion of existing and potential workers on the project could benefit from workplace experience, increased learning and development of their skills, knowledge and abilities. Increased skills levels would benefit workers by helping to make them more qualified and enhancing their employability and productivity.

10.4.15 Taking the above factors into account, the sensitivity of all the above categories of workers to impacts associated with the proposed development including the creation of employment and the potential improvement of skill levels is considered to be medium.

Freight by water sector

10.4.16 The receptors in this case are the businesses, including their owners and employees, which work directly or indirectly in the freight by water sector, as well as the business sector as a whole.

10.4.17 According to the latest consultation version of the GLA Safeguarded Wharves Review 2011/2012, the total tonnage of freight shipped on the GLA portion of the River Thames in 2010 was approximately 7.8 million tones (GLA, 2012)[22].

10.4.18 According to the GLA, the freight by water sector is a relatively under developed sector, despite it being promoted through planning policy due to its ability to take lorries off the road and boost sustainability (GLA, 2005)[23]. Even a relatively small increase in market share of the freight transportation sector could therefore represent a relatively significant increase in activity for the sector, and could help to enact a step change in the size and success of the sector.

10.4.19 Taking the above into account, the sensitivity of the freight by water sector to an increase in business opportunities is considered to be medium.

River Thames and public open space in London

10.4.20 The *London Plan 2011*[24] recognises the River Thames and its environs as an important component of both Greater London's strategic green infrastructure network and its multifunctional Blue Ribbon Network. As part of these networks, the river and its environs play an important role in promoting recreational opportunities, including water-based leisure and sporting activities such as rowing, canoeing and sailing, and also riverside walking and cycling. This in turn promotes healthy living. The *London Plan 2011* notes the importance of such recreational activities to healthy living for Londoners. It also recognises that the central stretches of the Thames are world famous locations, featuring well known landmarks and views.

10.4.21 The following sub-sections consider the two key London-wide recreational user groups of concern to this assessment, ie, users of water-side public open spaces, particularly those along the River Thames and users of the River Thames for water-based leisure and sport activities.

Recreational users of London's public open spaces including water-side open space

10.4.22 The receptors are people using public open space in London, particularly that alongside and associated with the River Thames and its environs, for leisure and recreation purposes.

10.4.23 The public open space and amenity space alongside the length of the River Thames, particularly in inner areas of London, is a mostly well used recreational resource. It is used for a range of activities including walking, jogging and cycling, and is also enjoyed as a resource for passive recreational pursuits such as sitting and enjoying views of adjacent landmarks and vistas.

10.4.24 Public open space along much of the Thames, and in particular within the vicinity of the proposed foreshore construction sites, is comprised predominantly[ix] of linear open spaces, pocket parks (under 0.4ha) and small open spaces (under 2ha) as defined and categorised by the GLA Open Space Hierarchy (GLA, 2011)[25]. The area of the public open space along the river is not known.

10.4.25 At a metropolitan level, Greater London has around 50,000ha of publicly accessible open space over 1ha in size (GLA, 2012)[26]. The type and distribution of open spaces is highly varied across Greater London, however the *London Plan 2011* concludes that there is relatively constrained access to open space in Inner London (GLA, 2011)[27].

10.4.26 Public open space and public access along the River Thames is often provided in association with, and in some cases as a result of, the existence of the Thames Path. The Thames Path follows the river for almost its entire length through Greater London, including within close proximity of all of the proposed construction sites that are located along the river foreshore. It provides an important asset for recreational walkers and cyclists, and is also routinely used by tourists, especially in inner London.

10.4.27 Given the amount of open space in London but also the relatively constrained access to open space in Inner London, the sensitivity of users of London's public open spaces is considered to be medium.

Recreational users of the River Thames for water-based leisure and sport activities

10.4.28 The receptors are people using the River Thames for water-based leisure, sport and recreational activities.

10.4.29 The River Thames is a well used recreational resource used for water-based leisure and sporting activities such as walking, jogging and cycling and waterborne activities including rowing, sailing, swimming and fishing.

[ix] The main exceptions of relevance to this assessment are Barn Elms, Ranelagh Gardens and the Royal Hospital Gardens (at Chelsea), Battersea Park and King Edward Memorial Park.

The key receptors to changes in the water quality of the River Thames, which would occur in the operational phase of the project through reduced sewage outflow, are the recreational river users themselves.

10.4.30 According to a study carried out in 2007, an estimated 3,000 to 5,000 people use the tidal section of the River Thames for water-based recreational purposes (EA cited in Lane, *et al.*, 2007)[28].

10.4.31 The surface water assessment (see Section 14 of this volume) has cited evidence that each discharge increases the risk of exposure to pathogens for river users who come into contact with water. It reviews an study of health impacts upon recreational users of the River Thames that was conducted and reported by the Health Protection Agency in 2007 (Lane *et al.*, 2007)[29] and which concluded that risk of infection can remain for two to four days following a spill as the water containing the sewage moves back and forward with the tide. The same study also noted that analysis of the illness events reported against discharges on the Tidal Thames shows that 77% of cases related to rowing activities undertaken within three days of a combined sewer overflow (CSO) spill.

10.4.32 Most river users such as rowers, canoeists and sailors are likely to be aware of the potential health risks that can arise from sewage discharge events. They are also likely to be aware of sewage discharge events when they occur due to a range of factors including visual evidence of sewage overflows into the river, users' knowledge and understanding of the problem and the type of weather event (ie, a significant rainfall event) that is likely to lead to an overflow, and use by rowers of sewage discharge warning systems operated by Thames Water (British Rowing website, 2012)[30]. As a result, many users of the river are understood to restrict their activities after a sewage discharge event, thereby placing a limit on the extent to which the River Thames is able to provide water-based recreational opportunities for Londoners.

10.4.33 Given the geographical size and significance of the River Thames, the distance to other major water bodies or the sea, and the fact London is a heavily urbanised area, many existing recreational river users are likely to find that the alternatives available to them for pursuing such activities are limited. It is considered that users are unlikely to completely avoid river related activities after a sewage discharge even though it has a negative effect on their health. This could be because they are unaware of the discharge or because they value their recreational activity very highly and have no other alternative.

10.4.34 Taking account of the above factors it is considered that recreational river users for water-based leisure and sporting activity are likely to have a high level of sensitivity to changes in the quality of the river water.

The London tourism sector

10.4.35 The receptor is the London tourism sector. According to VisitBritain the number of people who visited London for leisure and tourism purposes in 2010 was 14.7 million (Visit Britain, 2012)[31]. In comparison, the figure for the whole UK in 2010 was approximately 30 million, demonstrating the importance of London to the national leisure and tourism sector.

10.4.36 These people visit a wide range of attractions in London including public open space next to the River Thames. The River Thames provides a focus for tourism in London and is a major tourist destination in its own right. As a focus for the tourism sector, it is considered that the most high profile section of the river lies between Vauxhall Bridge and Tower Bridge.

10.4.37 Given that the River Thames is a significant attraction for visitors to London, it is likely that a high proportion of visitors to London would spend at least some time near the river, although it may not be a primary destination for all of them. However, London's tourism sector is broad based and highly varied and as such there are also a range of other significant attractions within London.

10.4.38 Given the wide range of alternative choice of locations available to tourists and leisure users their sensitivity of the London tourism sector to changes resulting from the proposed development is considered to be medium.

Summary

10.4.39 A summary of receptors as described in the baseline and their sensitivity is provided in Vol 3 Table 10.4.1.

Vol 3 Table 10.4.1 Socio-economics – receptor values / sensitivities

Receptor	Value / sensitivity and justification
Construction workers	Medium – while workers in Greater London generally have a range of employment opportunities available to them, jobs provide significant benefits to individuals such as a regular wage and longer term benefits such as workplace experience, skills, knowledge, abilities and personal financial stability.
Manufacturing workers	Medium – as above
Barge operating workers	Medium – as above
Other services workers	Medium – as above
Freight by water sector	Medium - an increase in market share of the freight transportation sector would be relatively significant and could help to enact a step change in the sector.
Recreational users of London's public open spaces including water-side open space	Medium – wide and varied availability of public open space in Greater London but access to public open space is relatively constrained in Inner London
Recreational users of the River Thames for water-based leisure and sport activities	High – the River Thames is a major resource for water-based leisure and sports activities in Greater London and access to alternative water-courses is likely to be limited for most users. Users are also likely to be sensitive to potential health risks associated with changes in river water quality

Receptor	Value / sensitivity and justification
The London tourism sector	Medium – London's tourism sector is broad based and highly varied and there are alternative locations available to tourists

Construction base case

10.4.40 For project-wide effects the base case year is the peak year of construction. The peak construction year for the project-wide assessment is assumed to be 2019.

10.4.41 The construction base case takes into consideration any changes to the baseline position described above. It takes account of major new infrastructure projects that are expected to be completed and partially or fully operational by the peak construction year.

10.4.42 The base case in the peak year of construction would differ from the baseline in the following ways:

Workers and employment

Construction workers

10.4.43 According to the GLA employment projections by 2019 there will be 208,000 construction jobs in London. This compares to the 2012 estimated figure of 227,000 and demonstrates that there is expected to be a decline of approximately 19,000 construction jobs between the current baseline and construction base case[x]. This represents a 8% total decline in construction employment.

10.4.44 For the assessment of cumulative effects the entire construction period of the proposed development is also considered alongside the peak construction year. This is because there will be varying crossovers of construction periods between the different projects. Therefore it is necessary to consider the GLA construction worker employment projection for the proposed development construction period of 2016 to 2022. This is shown in Vol 3 Table 10.4.2 below:

Vol 3 Table 10.4.2 Socio-economics – GLA construction employment projections

Year	Total projected construction jobs in Greater London
2016	216,000
2017	214,000
2018	211,000
2019	208,000
2020	206,000

Year	Total projected construction jobs in Greater London
2021	203,000
2022	201,000

10.4.45 Although the GLA employment projections were produced in 2010 and take account of the recent recession, since they were produced the national economy has further stagnated. This means it is possible that the GLA employment projections made in 2010 could overestimate future jobs[xi]. For this assessment this means that any new employment opportunities generated by the proposed development in the future could have a more significant effect when compared against a revised base case. However the London economy is performing better than the national economy. For example, according to the GLA real GVA growth in London in Quarter 2 of 2012 was 0.9% as opposed to -0.4% in the UK economy (GLA, 2012)[32]. Overall no discount to the GLA employment projections is deemed necessary.

10.4.46 The GLA construction employment projections do not take direct account of the jobs that are being and would be generated by the major developments identified in para. 10.3.8, ie, Crossrail, Thameslink and the North London (Electricity Line) Reinforcement Project. Although the GLA employment projection assumptions are at least partly based on projection forward of large historic construction projects together with general development they may not adequately account for the additional demand created by major projects such as Crossrail, Thames Tideway Tunnel project and Thameslink. The employment from these major schemes is considered as additional to the GLA employment projection figure in the assessment of project-wide effects.

Construction workers' skills levels

10.4.47 According to the BIS report on skills and resource capacity in the UK tunnelling construction sector, although there is sufficient capacity in the baseline, in the future when the proposed construction works are planned to occur there is likely to be a skills shortage due to the cumulative effect of the various large tunnelling projects that are planned such as Thames Tideway Tunnel project and Crossrail (BIS 2012).

10.4.48 A labour market intelligence report by ConstructionSkills and Experian forecast that between 2012 and 2016 there is likely to be a need for approximately 1,750 additional construction workers per year to meet expected demand (ConstructionSkills 2012)[33]. The key relevant skills that are estimated to be required annually include approximately 340 specialist building operatives, 200 plasterers and dry liners and 80 plant operators.

[xi] GLA employment projections (2010) are based on an underlying assumption of an average 2.5% per annum growth.

Manufacturing employment

10.4.49 The GLA employment projections predict a decline in manufacturing jobs, of which tunnel segment is a sub sector. The projection for 2019 is 141,000. This represents an approximate 23.4% decline from the existing baseline. The total projected number of jobs for the period 2016 to 2022 is shown in Vol 3 Table 10.4.3 below:

Vol 3 Table 10.4.3 Socio-economics – GLA manufacturing employment projections

Year	Total projected manufacturing jobs in Greater London
2016	158,000
2017	152.000
2018	146,000
2019	141,000
2020	135,000
2021	130,000
2022	125,000

Barge and boat operating workers and the freight by water sector

10.4.50 The number of barge and boat operating workers in employment and the state of the freight by water sector is interrelated, and it is useful to consider these receptors together with regard to the changes that would take place by the base case.

10.4.51 Between the baseline and the base case, several major projects may influence these receptors to varying degrees:

a. Based on information gained through consultation with the Company of Watermen and Lightermen it is understood that in 2019 the total jobs in the freight by water sector is likely to be less than that estimated currently. Based on their experience, the Company of Watermen and Lightermen estimate that the freight by water sector has an attrition rate of approximately 10% per annum due to significant amount of experienced boatmasters and barge-hands that are retiring and the small intake of new trainees. If this figure is applied to the current baseline it is estimated that in 2019 there would be approximately 1,000 individual workers that are ship and boat operators in total. This total figure includes approximately 200 Boatmasters and 800 barge hands and support staff and was derived through an interpolation of the makeup of a typical Thames vessel's crew. According to the GLA Safeguarded Wharves Review 2011/2012 estimates of future freight by water tonnage by 2019 there will be around 10 million tonnes of material shipped in the GLA portion of the River Thames (GLA, 2012).

b. Crossrail will use barges to transport some material in and out of some of the construction sites. Rail and road are also used to transport materials in and excavated material away from the site. It is understood (following consultation with the External Advisory Panel[xii]) that a minimal amount of additional barge operating jobs will be created by Crossrail. The majority of the excavated material is expected to be taken from the construction sites by ship to Wallasea in Essex and this will be performed through contracts with existing construction and logistics firms who it is assumed can accommodate the additional demand through their existing workforce. Therefore the level of demand placed on London's freight by water sector is expected to be minimal.

c. Some of the construction materials and excavated material connected to the Olympics Legacy Communities Scheme could be transported by barge although according to the Thames Tideway Tunnel project construction team in consultation with the External Advisory Panel this is only expected to be a small amount, with the majority being transported either by rail or road, and therefore the level of demand placed on London's freight by water sector is likely to be minimal.

River Thames – Public open space in London

10.4.52 As described in para. 8.3.5, the London Olympics Legacy Communities Scheme would be progressively completed from 2013 onwards. Associated with this project and of relevance to this assessment is that Queen Elizabeth Olympic Park would be complete and operational by the base case assessment year. In total the Queen Elizabeth Olympic Park will deliver over 100ha of publicly accessible open space; including over 13ha of green corridors and over 22ha of parks and gardens, much of which will be located along the River Lee and the associated tributaries and canals (Olympic Delivery Authority, 2012)[34].

10.4.53 The new park, which will be classified as Metropolitan Open Land, will provide Greater London with a significant new waterside public open space including pathways for walking, jogging and cycling and opportunities for passive waterside recreation; thereby enhancing opportunities for recreational pursuits similar to those offered by the Thames Path and the public open and amenity spaces along the River Thames.

The London tourism sector

10.4.54 With regard to tourist receptors in the construction base case year, Visit Britain estimate that tourist numbers for the UK would have increased to 39 million per annum by the peak construction year (Visit Britain, 2012)[35]. If the same proportional increase is applied to London, it would mean the visitor numbers would increase from 14.7 million to 19.1 million per annum.

[xii] The External Advisory Body is made up of experienced consultants and suppliers working in marine operations and the freight by water sector. It was set up by Thames Tideway Tunnel to advise on the water transport strategy element of the *Transport Strategy Construction Implementation Report* (2012).

Operational base case

10.4.55 The assessment year for the operational base case is Year 1 of operation. This is the first year that the Thames Tideway Tunnel project is expected to be fully operational.

Other services workers

10.4.56 The category of 'other services jobs' would include the maintenance jobs that are likely to occur in the operational phase. The GLA Employment projections (made in 2010) estimate that there will be approximately 614,000 other services jobs in London by 2023. This compares to the current estimated figure of 458,000. It implies an increase of 34.1% in other service employment with approximately 156,000 more other service jobs in the operational base case than the current baseline.

The London tourism sector

10.4.57 With regard to tourist receptors VisitBritain estimate that tourist numbers for the UK would have increased to 41 million in the operation base case year. If the same proportional increase is applied to London it would mean the visitor numbers would increase from 14.7 million to 20.1 million per annum.

10.5 Construction effects assessment

Employment generation and skills

Construction phase employment

10.5.1 It is estimated that the project would create approximately 4,250 gross direct jobs at the peak construction year. This estimate is based on the experience of constructing the Lee Tunnel, and professional judgement which has been applied to the proposed construction works to estimate the number of jobs created in the construction of the Thames Tideway Tunnel project.

10.5.2 To estimate the indirect jobs generated by the proposed development the following factors are considered:

Leakage

10.5.3 As described in the assumptions section above, a 13% discount is applied to the estimated 4,250 direct jobs created by the construction phase. It is thus estimated that 553 persons from outside Greater London and 3,698 persons from Greater London would be working at the proposed development during the construction period.

Displacement

10.5.4 As described in the assumptions section above, a 25% discount was applied to the estimated 4,250 direct jobs created by the construction phase to account for the displacement effect. It is thus estimated that 1,063 jobs would be displaced by the proposed development during the construction period. Net direct jobs are therefore estimated at 3,188.

Multiplier effect

10.5.5 As described in the assumptions section above, a factor of 219% was applied to the estimated 3,188 net direct jobs created by the construction phase to account for the multiplier effect. It is thus estimated that an additional 3,793 indirect jobs would be created by the proposed development during the construction period.

Deadweight effect

10.5.6 As described in the assumptions section above (see para. 10.3.13c) and Vol 2 Section 10.8, an estimate of employment at the proposed development sites that could be lost as a result of relocation during the construction period has been made. These jobs that would have occurred if the proposed development does not go ahead, represent the base case as defined in Vol 2 Section 10.

10.5.7 The method described in para. 10.3.13c results in an estimate of approximately 225 jobs on site; of which it is judged that one-third or the equivalent of 75 jobs could potentially be lost, thereby arriving at the gross deadweight jobs.

10.5.8 The same general assumptions, based on the HCA Additionality Guide, relating to displacement, leakage and the multiplier effect are then applied to this figure to arrive at a net deadweight figure of 96. The net deadweight figure of 96 is discounted from the net indirect jobs. As explained in Vol 2 Section 10 the result of this equation represents the net jobs after the development case is assessed against the base case.

Total indirect jobs and net employment

10.5.9 Vol 3 Table 10.5.1 presents the employment created by the proposed development in the construction phase (during the peak year) taking leakage, displacement, multiplier and deadweight effects into account. If the multiplier of 2.19 is applied to the 4,250 direct jobs an estimate of approximately 9,308 total gross jobs connected to the proposed development can be made. For the proposed development, the total net additional employment created within Greater London is estimated to be 5,990 persons and 895 outside Greater London, creating a total of 6,885 jobs during the peak year of the construction period.

Vol 3 Table 10.5.1 Socio-economics – net construction employment

	Greater London (peak year)	Outside of greater London (i.e. leakage) (peak year)	Total (peak year)
Gross Direct Employment	3,698	553	4,250
Displacement	-924	-138	-1,063
Net Direct Employment	2,773	414	3,188

	Greater London (peak year)	Outside of greater London (i.e. leakage) (peak year)	Total (peak year)
Net Indirect Employment	3,300	493	3,793
Net Deadweight	-83	-12	-96
Total Net Employment	**5,990**	**895**	**6,885**

Source: URS Calculations 2012. Note that figures do not always add up due to rounding

10.5.10 The magnitude of the above impact is influenced by the following factors:

a. Given the length of the construction phase (approximately seven years) many of the jobs created would be for the duration of the project. Therefore there would be a mix of medium and long term employment opportunities for workers.

b. The scale of the employment generated is significant. Approximately 4,250 new jobs represent around 2.0% of the total projected 211,000 jobs in the construction industry in the base case (GLA, 2010)[36].

c. It is also considered that both the size and the geographic scale of the project would ensure that jobs would go to workers living across a wide area of London and surrounding regions, most especially the South East and East of England.

d. As described in the community profile above, some of the boroughs that the proposed development passes through are some of the most deprived in the UK and are affected by issues including long term unemployment and skills mismatches. Therefore the creation of jobs and training schemes here represents a significant opportunity. This issue is addressed by Objective 3 of the *Skills and Employment Strategy* (which accompanies the application); ‘Promote opportunities for local people and disadvantaged groups’.

10.5.11 On the basis of the above, it is considered that employment generation during the construction phase of the proposed development would represent a high magnitude of impact.

10.5.12 Given the high magnitude of impact and the medium sensitivity it is likely that the creation of construction phase related employment would have a long-term **major beneficial** effect on Greater London construction workers.

10.5.13 Due to the major beneficial effect arising from construction employment, it is considered that the Thames Tideway Tunnel project construction process would have a beneficial impact within the local areas at each construction site. This is due to an increased number of employees at each site who would potentially help to support local businesses and the local economy by making use of and spending at facilities in the area, for example cafes, retail outlets and other businesses. This is accounted for in terms of the net indirect employment (see Vol 3 Table 10.5.1).

Tunnel segment manufacturing employment

10.5.14 Tunnel segment manufacturing is considered to be a sub-set of the indirect jobs arising as a result of the construction phase as shown at Vol 3 Table 10.5.1 above. An assessment of this particular element is outlined below.

10.5.15 Construction of the segments required to form the tunnel would create jobs off site from the proposed project sites. It is estimated that approximately 100 jobs would be directly created by the construction of the tunnel segments (i.e. this forms an element of the 493 indirect jobs estimated to be created outside London). It is possible that the work would be split between factories to serve the eastern and western drive sites respectively.

10.5.16 The magnitude of the above impact is influenced by the following factors:

a. The scale of employment generation (100 jobs) is small compared to the total manufacturing employment during the base case.

b. It is understood that these jobs would likely last for approximately one year and so would be temporary and short to medium term in nature.

10.5.17 Given the above factors it is considered that the impact magnitude would be low.

10.5.18 Given the medium sensitivity of the workers in this sector and the low magnitude of the impact the overall effect is likely to be **minor beneficial**.

Barge operation related employment generation

10.5.19 Barge and ship operation is considered to be a sub-set of the indirect jobs arising as a result of the construction phase as shown at Vol 3 Table 10.5.1. Details of this particular element are outlined below for information purposes.

10.5.20 During the construction phase river barges and ships would be used to transport a proportion of construction materials and excavated material. It is currently estimated that approximately 10,780 additional barge movements would be created by the proposed development. These movements would generate an additional 274 direct new barge and ship operating jobs.

10.5.21 The magnitude of the above impact is influenced by the following factors:

a. The scale of employment generation above is significant compared to total barge operating employment in London during the base case of approximately 1,000 jobs.

b. These jobs would likely last for the entire construction period of approximately six years and so would be long term in nature.

10.5.22 Given the above factors, the impact magnitude would be high.

10.5.23 Give the medium magnitude of impact and the medium sensitivity of the freight by water sector workers the effect would be **major beneficial**.

Effect on worker skills levels

10.5.24 The creation of employment opportunities is likely to lead to an increase in the skill level of individuals and the workforce as workers acquire skills through ‘on the job’ experience and potential specific training initiatives. With regard to the requirement for skilled labour, the following construction related activities are considered to potentially require bespoke skilled trades people:

a. Tunnelling activities

b. Barge operation

c. Engineering

d. Design.

10.5.25 A *Skills and Employment Strategy* for the Thames Tideway Tunnel project has been produced to accompany the application for which this assessment has been prepared. Of particular relevance to an assessment of the effect on worker skills levels is Objective 2 which is to ensure that a suitable workforce with the right skills is available to deliver the project. Activities that would be pursued to achieve this objective would include:

a. ensuring that there is a minimum one apprentice for every 50 site employees at all times throughout the construction contracts

b. supporting the ongoing operation of the Tunnelling and Underground Construction Academy (TUCA) and the development of river-transport related skills through the Thames Training Alliance

c. setting up mechanisms for the ongoing monitoring of skills gaps and training requirements

d. establishing a Skills Planning Group to identify future training requirements and potential interventions.

10.5.26 The magnitude of the impact is influenced by the following factors:

a. The permanency of the skills - as they are specialist skills they are likely to help workers to gain employment over the longer term.

b. It is not possible at this stage to define the exact scale and type of specialist skills that are likely to be gained. Some of the most specialist jobs, eg, the tunnel engineers, are likely to be taken by highly skilled individuals that move across the globe to wherever major tunnelling opportunities occur. In addition, some of the likely specialist trades-people required (particularly those related to tunnelling activities) would have already been trained up to meet the requirements of the Crossrail project.

c. The number of people who could increase their skills levels compared to the overall construction and barge operation workforce in the base case would be reasonably significant. The estimated number of people who would increase their skill level through participation in the proposed development is equivalent to approximately 1.5% of the construction workforce and 35% of the barge operation workforce. This is based on an assumption that all people employed during the construction phase would increase their skills levels. The scale of the increase in skills levels implies benefits for the respective industries, and the Greater London economy, as a whole.

10.5.27 Taking account of the above, the impact magnitude is likely to be medium.

10.5.28 Given the medium magnitude of impact and the medium sensitivity of London’s construction and barge operation workforces there would be a **moderate beneficial** effect on the skill levels of these workers.

Stimulation of the freight by water sector

10.5.29 The increased use of wharves and barges to move a proportion of construction materials and excavated material to and from the proposed development sites could stimulate development of the freight by water sector.

10.5.30 This would have a variety of benefits, including benefits to the local economy, through stimulating employment and related economic activity. It would also encourage the shift towards more sustainable (lower carbon) transport modes which would help to achieve wider sustainability objectives.

10.5.31 The magnitude of the impact is influenced by the following factors:

a. Under the logistics scenario currently under consideration, the construction phase is estimated to create a total of approximately 5,400 additional barge movements and 274 additional employment opportunities. Also, according to the GLA Safeguarded Wharves Review 2011/2012 the proposed development will involve the shipping of approximately 4 million tonnes of material in total on the GLA portion of the River Thames during the construction period. When considered against the base case of 1,000 jobs in the freight by water sector and the approximately 10 million tonnes of material per annum shipped in the GLA portion of the River Thames this is considerable.

b. Although the construction period is temporary it should last up to six years so it is deemed long term. A six year long expansion of the freight by water sector could help to change industry perceptions and hauliers’ opinions on the viability and practicality of using barges to transport excavated material and construction materials around London. It could also help to create a critical mass of barge operating resources that could expand the range of freight handling services available to hauliers.

c. Consideration is made of the temporary loss during the construction phase of two moorings at Chambers Wharf and King Edward Memorial Park. Also, two further moorings at Victoria would be lost although one returned after construction. However, in the context of the freight by water sector as a whole and based on consultation with the mooring owners at Victoria the effect of these losses on the business operations of the freight by water sector is deemed to be negligible.

10.5.32 Taking account of the above factors, it is considered that the magnitude of impact would be high.

10.5.33 Given the high impact magnitude impact and the medium sensitivity of the receptor the effect in terms of stimulating the freight by water sector would be **major beneficial**.

Recreation, leisure and tourism effects

Temporary decrease in public open and amenity space

10.5.34 The project would involve construction activities at a 24 construction sites in Greater London including four located within designated public open spaces and 11 located directly on the River Thames foreshore at sites where facilities such as the Thames Path and associated public amenity space provide opportunities for recreation and leisure and, as well as tourism.

10.5.35 The magnitude of the impact is influenced by the following factors:

a. Overall, the duration of the impact would be largely medium term

b. In terms of leisure and recreational facilities, the impact is likely to be limited to a small number of discrete sites, and would not materially change the availability of leisure and recreational facilities at the Greater London spatial level.

10.5.36 Taking account of the above, it is considered that magnitude of impact would be negligible.

10.5.37 Given the negligible magnitude of impact and the medium sensitivity the effect on recreational users of public open space in Greater London would be **negligible**.

Temporary effect on the London tourism sector

10.5.38 The project would result in construction activities at a 24 construction sites in Greater London including three located between Vauxhall Bridge and Tower Bridge where tourism activity along the River Thames is most highly concentrated.

10.5.39 The magnitude of the impact is influenced by the following factors:

a. Overall, the duration of the impact would be largely medium term

b. While tourists are likely to be aware of the construction site when they arrive within the vicinity of a proposed construction site, most are unlikely to have prior knowledge of the works taking place. Even if potential tourists do become aware of the works prior to their visit, the scale of the works, the relatively few sites within inner London, and the range of alternative attractions would all mean that the number of tourists coming to London would be very unlikely to decline. At worst, tourists and tourism expenditure might be temporarily displaced from certain sites, but they would be able to relocate their activities to other Greater London locations and tourist attractions.

c. Therefore, it is unlikely that there would be an impact on tourist numbers or the tourist economy at the Greater London spatial level.

10.5.40 Taking account of the above factors, it is considered that magnitude of impact would be negligible.

10.5.41 Given the negligible magnitude of impact and the medium sensitivity, it is assessed that the effect on the London tourism sector would be **negligible**.

10.6 Operational effects assessment

Employment generation

Operational phase employment

10.6.1 The proposed development would generate a requirement for maintenance activities during the operational phase, categorised as falling with the 'other services' sector. However, the overall number of equivalent full time employment opportunities that would be created in the operational phase is likely to be small in number.

10.6.2 The magnitude of the impact is influenced by the following factors:

a. The employment created would be permanent and long term, as maintenance of the facility would be an ongoing requirement throughout the project's operational lifespan, which is likely to be at least one hundred years.

b. The number of jobs created when compared to the base case of 'other service' jobs in Greater London would be relatively small.

10.6.3 Taking account of the above factors, it is considered that the magnitude of the impact would be negligible.

10.6.4 Given the negligible impact magnitude impact and the medium sensitivity of the receptor there would be a **negligible** effect arising from operational employment.

Recreation, leisure and tourism effects

Permanent increase in public open and amenity space

10.6.5 The installation of above-ground structures, as described in the relevant site specific volumes[xiii], would result in the extension of the existing river wall out into the River Thames. This would create eight new or extended small areas of public open or amenity space in the operational phase along the River Thames. The extensions to the public realm have been assessed within the relevant site specific volumes in terms of the potential additional recreational opportunities and benefits that they would create and the following assessment considers the effect on the provision of open space at the project-wide level.

10.6.6 This assessment of the impact magnitude is based on the following considerations:

[xiii] Relevant sites are Putney Embankment Foreshore, Carnwath Road Riverside, Chelsea Embankment Foreshore, Heathwall Pumping Station, Albert Embankment Foreshore, Victoria Embankment Foreshore, Blackfriars Bridge Foreshore and King Edward Memorial Park.

a. The new public open spaces would provide a permanent increase in public amenity space alongside the river and the Thames Path and the impact on users would be long term

b. The net increase in terms of amenity space would be small in relation to the total area of public amenity and open space available at the Greater London level in the base case. As such, it would not materially change the availability of leisure and recreational facilities at the Greater London spatial level. However, given the constrained access to public open space in Inner London, it would still be beneficial for users.

10.6.7 Additionally, the Thames Tideway Tunnel project's *Health Impact Assessment* (*HIA*) (which accompanies the application) has concluded that there would be a moderate beneficial effect in terms of access to open and green spaces (as a determinant of public health) at the project wide level.

10.6.8 Taking account of the above, the magnitude of the impact is considered to be low.

10.6.9 Given the low magnitude of magnitude and the medium sensitivity of the receptor there would be a **minor beneficial** effect on recreational users of public open space and amenity space, in particular along the River Thames, from the net increase in such space.

Effect on recreational users of the River Thames for water-based leisure and sport activities

10.6.10 In its operational phase, the project is expected to result in an improvement in the water quality of the River Thames (see Section 14 of this volume). There would also be an improvement to the visual appearance of the river, as a result of a reduction in sewage effluent and sewage derived litter. An increase in water quality and change in perceptions of river cleanliness can be expected to lead to an increase in river related recreational opportunities for Londoners.

10.6.11 The magnitude of the impact is influenced by the following factors:

a. The impacts would be permanent and long term.

b. The impact would be most directly experienced by an estimated 3,000 to 5,000 people who use the tidal section of the River Thames for recreational purposes.

c. The reduction in the number of spill days, and the subsequent improvement in the quality of the water, would significantly improve the experience for recreation users of the River Thames in the base case. This is based on the surface water resources section (Section 14 of this volume) which states that sewer network modelling results show that in a typical year the Thames Tideway Tunnel project would:

i Reduce the total volume of combined sewage entering the river by 15,250,000m^3 or 87% in the typical year when compared to the operational base case ii Reduce the maximum number of days with CSO spills occurring in the Tideway from 54 days to 7 days.

iii Reduce the maximum length of time that spills occur (when combined) to the Tideway from 698 hours down to 36 hours.

iv The likely reduction in spill frequency in the operational phase of the Thames Tideway Tunnel project would significantly reduce the number of days that users of the river would be at risk of exposure by between approximately 86% and 94% for the three sections of river located between Teddington and Greenwich (see Vol 3 Section 14.6), thereby benefiting recreational users of the river.

d. It is likely that awareness of the improvements in river water quality would lead to an increase in public interest in the opportunities provided by the river for water based recreational activity. This may lead to an increase in participation levels of river based recreational and leisure activities.

10.6.12 In addition to the conclusions of the Water resources – surface water assessment, the Thames Tideway Tunnel project's *HIA* has concluded that there would be a moderate to major beneficial effect in terms of water quality for recreational river users (as a determinant of public health) at the project wide level.

10.6.13 Overall, on the basis of the above factors, it is considered that the magnitude of the impact would be medium.

10.6.14 Given the medium magnitude of impact and the high sensitivity of users, the effect of improving the quality of the River Thames on recreational users' of the river for water-based leisure and sport activities would be **major beneficial**.

10.7 Cumulative effects assessment

Construction effects

10.7.1 For the purposes of this cumulative assessment, the assessment year is the peak construction year.

10.7.2 As described in Section 10.4, one project, the London Olympics Legacy Communities Scheme would be under construction at the same time in the peak year of construction as the Thames Tideway Tunnel project. The on-going construction of the Olympics Legacy Scheme would generate employment for construction workers in the same manner as would the Thames Tideway Tunnel project. As such, it could give rise to cumulative effects on socio-economic receptors, specifically workers, in the peak year of construction.

10.7.3 The current estimate of Olympic Legacy project construction jobs in 2019 is approximately 2,100 (Olympic Park Legacy Company, 2011)[37].

10.7.4 Crossrail, Thameslink and the North London (Electricity Line) Reinforcement Project are due to be completed by 2018 and so they would not be under construction in the peak year, and therefore they are not strictly relevant to the peak year cumulative effect assessment.

However, as described in para. 10.3.8, all of these three schemes (wholly or at least in part) would still be under construction in Project Year 1 of the Thames Tideway Tunnel project construction phase. Therefore, the final year(s) of the construction phases of those projects would overlap with the commencement year(s) of the construction phase for the Thames Tideway Tunnel project. As such, it is noted that there would be likely to be cumulative effects in terms of construction related employment generation with these schemes during the periods when these projects overlap with the beginning of the construction of the Thames Tideway Tunnel project. However they could be relevant during the early years of construction at the proposed development and therefore all schemes are considered below.

10.7.5 For Crossrail, the total estimated number of construction jobs created by Crossrail in the peak construction year is approximately 16,000 (Crossrail, 2007)[38]. The later ‘Crossrail Business Case 2010’ revised down the estimate of direct construction jobs to 14,000 (Crossrail, 2007)[39].

10.7.6 For Thameslink, it is estimated that an average of 2,300 direct construction jobs per year will be created by Thameslink during the five years of construction (Thameslink, 2004)[40].

10.7.7 The North London (Electricity Line) Reinforcement Project is planned to be under construction between 2015 and 2016 (National Grid, 2012)[41]. By the peak construction year it should be fully completed. It will generate additional construction employment, however no estimate is available.

10.7.8 Having considered each of the assessments undertaken in Section 10.5, it is considered that the overlap of the proposed development with these other projects may lead to elevated effects on construction and barge operation workers. As the effect of the proposed development on construction workers and barge operation workers is assessed as being significant the cumulative effect is expected to remain significant. Given the other projects do not involve elements of tunnel manufacturing, it is considered that the development would not affect the significance of the effects on this receptor.

10.7.9 These elevated effects relate to the creation of additional job opportunities and increased skills levels at the peak year and from Site Year 1 until the proposed development construction ends.

10.7.10 There could also be elevated effects in terms of the stimulation of the freight by water sector in the same years, as described above. This is because Crossrail and the Olympics Legacy Communities Scheme are likely to transport some building materials and excavated material by barge during their construction periods.

10.7.11 There are not likely to be elevated effects on the recreation, leisure and tourism receptors at a cumulative level. This is because no significant effects on these receptors have been identified for the proposed development and although there will be temporary adverse effects on these receptors for the Crossrail and Thameslink projects, these will largely occur in different locations and at different times to the proposed development.

Operational effects

10.7.12 As described in Section 10.3, there are no other developments that could have the same type of effect as that considered in Section 10.6 and therefore, no cumulative effects require consideration.

10.7.13 Therefore, the effects on socio-economic receptors would remain as described in Section 10.6.

10.8 Mitigation

10.8.1 The above assessment has concluded that construction and operational project-wide effects would be either negligible or beneficial and therefore mitigation is not needed.

10.8.2 A *Skills and Employment Strategy* for the Thames Tideway Tunnel project has been produced to accompany the application. This strategy contains objectives and activities that seek to enhance the outcomes of the project for socio-economic receptors including existing and potential workers within various industry sectors and local businesses. These objectives and activities have been taken into account where relevant within the construction phase effects assessment in Section 10.5. See the *Skills and Employment Strategy* which accompanies the application for further details on how Thames Water aims to maximise the economic benefits of the proposed development.

10.9 Residual effects assessment

Construction effects

10.9.1 As no mitigation measures are proposed, the residual project-wide construction effects remain as described in Section 10.5.

10.9.2 All residual effects are summarised in Vol 3 Table 10.10.1.

10.9.3 There is an opportunity for the project to have a lasting beneficial economic and social impact as a result of the number of employment opportunities that the project would create and the legacy in terms of skills development. As the objectives and activities within the *Skills and Employment Strategy* have been taken into account within the construction phase effect assessment in Section 10.5, it is considered that residual effects would not change.

Operational effects

10.9.4 As no mitigation measures are proposed, the residual project-wide operational effects remain as described in Section 10.6.

10.9.5 All residual effects are summarised in Vol 3 Table 10.10.2.

10.10 Project-wide effects assessment summary

Vol 3 Table 10.10.1 Socio-economics - summary of construction assessment

Receptor	Effect	Significance of effect	Mitigation	Significance of residual effect
Construction workers	Creation of additional employment opportunities	Major beneficial	None	Major beneficial
Tunnel segment manufacturing workers	Creation of additional employment opportunities	Minor beneficial	None	Minor beneficial
Barge operation related workers	Creation of additional employment opportunities	Major beneficial	None	Major beneficial
Construction phase workers (various sectors)	Increased skills levels	Moderate beneficial	None	Moderate beneficial
Greater London freight by water sector	Stimulation of the freight by water sector	Major beneficial	None	Major beneficial
Recreational users of London's public open spaces including water-side open space	Temporary decrease in public open and amenity space	Negligible	None	Negligible
The London tourism sector	Temporary effect on the London tourism sector due to construction activity	Negligible	None	Negligible

Vol 3 Table 10.10.2 Socio-economics - summary of operational assessment

Receptor	Effect	Significance of effect	Mitigation	Significance of residual effect
Operational phase workers (project maintenance)	Creation of additional employment opportunities	Negligible	None	Negligible
Recreational users of London's public open spaces including water-side open space along the River Thames	Permanent increase in public open and amenity space	Minor beneficial	None	Minor beneficial
Recreational users of the River Thames for water-based leisure and sport activities	Improved river related recreational opportunities as a result of improved river quality	Major beneficial	None	Major beneficial

10.11 Summary of significant effects at all sites

10.11.1 Significant adverse (pre-mitigation) construction effects on socio-economic receptors have been identified at 11 sites as a result of either effects on the amenity of receptors, the displacement of business or facilities, or a reduction or loss of open space. All of these sites would also have significant adverse residual effects. Vol 3 Table 10.11.1 provides a summary of the significant effects identified at individual sites across the project.

10.11.2 No further practicable on-site mitigation can be adopted above those measures identified in the *CoCP* Parts A and B. A compensation programme has been established (see Schedule 2 of the *Statement of Reasons*, which accompanies this application) to address claims of exceptional hardship or disturbance. The assessments have included this compensation as mitigation for those receptors that could incur a financial cost as a result of disturbance arising during the construction phase. The residual effects presented in Vol 3 Table 10.11.1 therefore take the offsetting effects of these measures into account. For residential receptors who submit a claim for compensation, there is no guarantee that the affected parties would be eligible for compensation or that the compensation would be accepted by the affected party. The residual effects at residential properties reported in the *Environmental Statement* and presented in Vol 3 Table 10.11.1 therefore do not take the compensation programme into account.

10.11.3 No significant adverse effects on socio-economic receptors are predicted during the operation of the Thames Tideway Tunnel project. However significant beneficial operational effects have been identified at three sites as a result of permanent gain of public amenity space/realm.

10.11.4 The effects presented in Vol 3 Table 10.11.1 below represent a summary of the site-specific effects presented in Section 10 of Vols 4 to 27, and do not constitute additional effects arising from the proposed development.

Vol 3 Table 10.11.1 Socio-economics –summary of significant effects at all sites

Significance of effect	Receptor	Description of effect	Sites with significant effects (pre-mitigation)	Sites with significant residual effects
Construction – adverse	Residents of nearby property	Effects on residential amenity	Hammersmith Pumping Station (see Vol 5 Section 10) Barn Elms (see Vol 6 Section 10) Putney Embankment Foreshore (see Vol 7 Section 10) Carnwath Road Riverside (see Vol 10 Section 10) Cremorne Wharf Depot (see Vol 12 Section 10) Kirtling Street (see Vol 14 Section 10) Chambers Wharf Depot (see Vol 20 Section 10) Earl Pumping Station (see Vol 22 Section 10) King Edward Memorial Park Foreshore (see Vol 21 Section 10)	Hammersmith Pumping Station (see Vol 5 Section 10) Barn Elms (see Vol 6 Section 10) Putney Embankment Foreshore (see Vol 7 Section 10) Carnwath Road Riverside (see Vol 10 Section 10) Cremorne Wharf Depot (see Vol 12 Section 10) Kirtling Street (see Vol 14 Section 10) Chambers Wharf Depot (see Vol 20 Section 10) Earl Pumping Station (see Vol 22 Section 10) King Edward Memorial Park Foreshore (see Vol 21 Section 10)
	Residents	Effect on residents who may be eligible for and take up the option of temporary relocation	Putney Embankment Foreshore (See Vol 7 Section 10) Kirtling Street (see Vol 14 Section 10)	Putney Embankment Foreshore (See Vol 7 Section 10) Kirtling Street (see Vol 14 Section 10)

Significance of effect	Receptor	Description of effect	Sites with significant effects (pre-mitigation)	Sites with significant residual effects
	Business	Effects on business due to construction activity	Putney Embankment Foreshore (See Vol 7 Section 10) Victoria Embankment Foreshore (Tattershall Castle Vessel and Hispaniola Vessel) (see Vol 17 Section 10)	Victoria Embankment Foreshore (Hispaniola Vessel) (see Vol 17 Section 10)
	Educational facility	Effects of the amenity of staff and pupils	Deptford Church Street (St Joseph's RC Primary School) (see Vol 23 Section 10) King Edward Memorial Park Foreshore (Pier Head Montessori Preparatory School (see Vol 21 Section 10)	Deptford Church Street (St Joseph’s RC Primary School) (see Vol 23 Section 10) King Edward Memorial Park Foreshore (Pier Head Montessori Preparatory School (see Vol 21 Section 10)
	Place of worship	Effects on the amenity of the church and its users	Deptford Church Street (see Vol 23 Section 10)	
	Users of public open space	Effects on users from the temporary reduction in the provision of public space	King Edward Memorial Park Foreshore (see Vol 21 Section 10)	King Edward Memorial Park Foreshore (see Vol 21 Section 10)
	Users of Public Open Space	Effects on the amenity of public open space users	King Edward Memorial Park (see Vol 21 Section 10)	King Edward Memorial Park (see Vol 21 Section 10)

Significance of effect	Receptor	Description of effect	Sites with significant effects (pre-mitigation)	Sites with significant residual effects
Operational - beneficial	Users of public amenity/open space (future)	Permanent gain of public amenity space	Blackfriars Bridge Foreshore (see Vol 18 Section 10) King Edward Memorial Park Foreshore (see Vol 21 Section 10)	Blackfriars Bridge Foreshore (see Vol 18 Section 10) King Edward Memorial Park Foreshore (see Vol 21 Section 10)
	Users of landscape public realm	Permanent gain of new public realm	Carnwath Road Riverside (see Vol 10 Section 10)	Carnwath Road Riverside (see Vol 10 Section 10)

References

[1] Thames Tideway Strategic Study (TTSS). *Cost Benefit Analysis - Working Group Report* (2005).

[2] NERA for Thames Water. *Thames Tideway Cost Benefit Analysis* (2007).

[3] Department for environment Food and Rural Affairs (DEFRA). *Regulatory impact Assessment – sewage collection and treatment for London* (2007).

[4] Jacob Babtie. *Review of TTSS* (2006).

[5] DEFRA. *Creating a River Thames Fit for our Future* (2011).

[6] Thames Water. *Why Does London's Economy Need the Thames Tunne*l (2012)?

[7] Office for National Statistics*. 2001 Census* (2001).

[8] Homes and Communities Agency. *Economic Analysis - Additionality Guidance*; Third Addition (2008).

[9] Homes and Communities Agency. *Employment Densities Guide 2nd Edition* (2010).

[10] Scottish Executive. *Input-Output Multipliers 1998 – 2007* (2007).

[11] Thames Water. (2012). See citation above.

[12] L.E.K. Consultants. *Construction in the UK Economy: The Benefits of Investment: A study commissioned by the UK Contractors Group* (2009).

[13] Department for Business Innovation and Skills (BIS). *Research to improve the assessment of additionality* (2009).

[14] Department for Communities and Local Government. *Index of Multiple Deprivation 2010* (2010). Available at: http://www.communities.gov.uk/communities/research/indicesdeprivation/deprivation10/

[15] Greater London Authority. *Working Paper 38 London Employment Forecasts*, GLA (2010).

[16] Port of London Authority. *Port of London Economic Impact Assessment* (SQW Consulting) (2009).

[17] Port of London Authority Website. Available at: http://www.pla.co.uk/handbook/port_community.cfm/flag/3/class_id/88. Accessed August 2011.

[18] Peter Brett Associates. *Thames Tideway Tunnel Transport Strategy Construction Implementation Report* (2012).

[19] Department for Business Innovation and Skills (BIS). *Tunnelling: A Capability Anal*ysis (2012).

[20] Thames Water. *Transport Strategy Construction Implementation Report* (2012).

[21] Office for National Statistics. *Labour Market Statistics November 2012* (2012).

[22] Greater London Authority. *Safeguarded Wharves Review 2011/2012 Further Consultation Draft – July 2012* (2012).

[23] Greater London Authority. *Safeguarded Wharves on the River Thames* (2005).

[24] Greater London Authority. *London Plan – Spatial development strategy for Greater London* (2011).

[25] Greater London Authority. (2011), See citation above. p. 180.

[26] Greater London Authority. *Green infrastructure and open environments: The All London Green Grid Supplementary Planning Guidance* (2012). p. 44.

[27] Greater London Authority. (2011), See citation above. p. 52.

[28] Environment Agency cited in Lane, et al. *The Thames Recreational Users Study* (Produced by a collaborative partnership project between the City of London Port Health Authority and Health Protection Agency) (2007).

[29] Lane, C, Surman-Lee, S, Sellwood, J and Lee, JV. *The Thames Recreational Users Study Final Report* (2007).

[30] British Rowing website. Available at http://www.britishrowing.org/news/sewage-tideway-early-warning-system-thames. Accessed March 2012.

[31] Visit Britain. *Inbound Visitor Statistics* (2012).

[32] Greater London Authority. *London's Economy Today* (February November 2012 edition).

[33] ConstructionSkills. *2012-2016 Construction Skills Network Greater London: Labour Market Intelligence* (2012).

[34] Olympic Delivery Authority. *Legacy Communities Scheme Planning Applicati*on (Volume 2 – Main Committee Report June 2012). p. 369 – 371.

[35] Visit Britain. *Foresight Issue 100* (February 2012).

[36] Greater London Authority. *Employment Forecasts* (2010).

[37] Olympic Park Legacy Company. *Legacy Communities Scheme: Employment Statement* (Sept 2011).

[38] Crossrail. *Environmental Statement, Volume 1 Project Description* (2007).

[39] Crossrail. *Crossrail Business Case: A Summary* (2010).

[40] Thameslink 2000. *Sustainability Appraisal* (2004).

[41] National Grid. National Grid (North London Reinforcement Project) *Environmental Statement* (2012).

This page is intentionally blank

Thames Tideway Tunnel
Thames Water Utilities Limited

Thames Water

Application for Development Consent

Application Reference Number: WWO10001

Environmental Statement

Doc Ref: **6.2.03**

Volume 3: Project-wide effects assessment

Section 11: Townscape and visual

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

Hard copy available in

Box **17** Folder **A**
January 2013

Thames Tideway Tunnel
Creating a cleaner, healthier River Thames

This page is intentionally blank

Thames Tideway Tunnel

Environmental Statement

Volume 3: Project-wide effects assessment

Section 11: Townscape and visual

List of contents

Page number

List of tables

Page number

This page is intentionally blank

11 Townscape and visual

11.1 Introduction

11.1.1 Project-wide construction and operational effects for townscape and visual have been scoped out as explained in Volume 2 Section 11.1. This is on the basis that no significant effects are anticipated during either construction or operation beyond those assessed at a site level.

11.1.2 This section nevertheless presents details of engagement, an overview of the reasons why project-wide effects (as defined in this *Environmental Statement*) have been scoped out and a summary of the significant effects identified at individual sites across the project.

11.2 Engagement

11.2.1 Volume 2 documents the overall engagement which has been undertaken in preparing the *Environmental Statement*. No specific comments relevant to the assessment of project-wide effects on townscape and visual have been received.

11.2.2 English Heritage and local authorities within the townscape and visual assessment area of individual sites have been consulted on the number and location of viewpoints for the visual assessment. For some sites along the river, sequential views towards one or more site have been included to represent visual effects on recreational users of the Thames Path. However, these are all reported in the relevant site volumes as the visual effects relate to sites which are located relatively close to each other (see Section 11 in Vols 4 to 27). It was not considered that there were substantial enough visual receptors which would experience a greater number of sites at a project-wide scale. This overall approach was set out in the *Scoping Report*, which was not commented on by any stakeholders consulted.

11.2.3 In March 2011 English Heritage and the Environment Agency were consulted on the scope of the townscape and visual and ecology assessments through a series of site visits to a number of sites along the river. During these visits, English Heritage confirmed that, in their opinion, there was very limited potential for intervisibility of sites and therefore users of the Thames Path experienced effects from individual sites rather than at a project-wide scale.

11.3 Overview

11.3.1 Effects on townscape character and visual receptors relate to the removal, changing of or addition of components within the site, setting of surrounding character areas or the field of view of surrounding visual receptors. These changes would arise from individual sites or, in some instances along the River Thames, intervisibility of multiple sites.

Therefore, the assessment of townscape and visual effects is reported fully in the site volumes (see Section 11 of Vols 4 to 27) .

11.3.2 Effects on mobile visual receptors, such as users of the Thames Path, are considered through sequential viewpoints whereby one receptor may experience a series of views towards one or more Thames Tideway Tunnel sites. The scope of these have been agreed in consultation with English Heritage and local authorities within the townscape and visual assessment area, and relate only to sites which are relatively close together rather than at a project-wide scale. Therefore, these effects are also reported in the site volumes.

11.3.3 In addition, underground tunnelling activities associated with the construction and operation of the main and connection tunnels would take place at considerable depth and so would not have an effect on townscape character areas (including the tranquillity of these areas) and visual receptors.

11.3.4 Therefore, no project-wide assessment has been undertaken for this topic.

11.4 Summary of significant effects at all sites

11.4.1 Significant adverse effects on townscape and visual receptors have been identified at 23 sites as a result of the long duration and high visibility of construction activities and, at Chelsea Embankment Foreshore only, the high visibility of the proposed foreshore structure within a highly sensitive stretch of the River Thames. Vol 3 Table 11.4.1 provides a summary of the significant effects identified at individual sites across the project.

11.4.2 Mitigation measures have been identified and are described where relevant within Section 11 of Vols 4 to 27; these include advance planting at King Edward Memorial Park Foreshore. However, for the majority of sites, no further mitigation during construction is possible due to the highly visible nature of the construction activities. A process of iterative design and assessment has been employed to reduce adverse effects during operation. At the majority of sites (with the exception of Chelsea Embankment Foreshore), no further mitigation is required as no significant adverse effects are predicted.

11.4.3 As explained in Section 11.3 above, effects identified at individual sites would not result in project-wide effects, (as defined in this *Environmental Statement*) when considered together across the project area.

11.4.4 Vol 3 Table 11.4.1 below provides a summary of the likely significant site specific effects presented in Volumes 4 to 27. It does not represent additional effects arising from the proposed development.

Vol 3 Table 11.4.1 Townscape and visual – summary of significant effects at individual sites

Significance of effect	Receptor	Description of effect	Sites with significant effects (pre-mitigation)	Sites with significant residual effects
Construction – adverse	Townscape character areas of high sensitivity	Change to the character or setting of an area due to the presence of construction activity.	Hammersmith Pumping Station (Vol 5 Section 11) Barn Elms (Vol 6 Section 11) Putney Embankment Foreshore (Vol 7 Section 11) King George's Park (Vol 9 Section 11) Carnwath Road Riverside (Vol 10 Section 11) Cremorne Wharf Depot (Vol 12 Section 11) Chelsea Embankment Foreshore (Vol 13 Section 11) Albert Embankment Foreshore (Vol 16 Section 11) Victoria Embankment Foreshore (Vol 17 Section 11) Blackfriars Bridge Foreshore (Vol 18 Section 11) Shad Thames Pumping Station (Vol 19 Section 11) Chambers Wharf (Vol 20 Section 11) King Edward Memorial Park Foreshore (Vol 21 Section 11) Deptford Church Street (Vol 23 Section 11) Abbey Mills Pumping Station (Vol 25 Section 11)	Hammersmith Pumping Station (Vol 5 Section 11) Barn Elms (Vol 6 Section 11) Putney Embankment Foreshore (Vol 7 Section 11) King George's Park (Vol 9 Section 11) Carnwath Road Riverside (Vol 10 Section 11) Cremorne Wharf Depot (Vol 12 Section 11) Chelsea Embankment Foreshore (Vol 13 Section 11) Albert Embankment Foreshore (Vol 16 Section 11) Victoria Embankment Foreshore (Vol 17 Section 11) Blackfriars Bridge Foreshore (Vol 18 Section 11) Shad Thames Pumping Station (Vol 19 Section 11) Chambers Wharf (Vol 20 Section 11) King Edward Memorial Park Foreshore (Vol 21 Section 11) Deptford Church Street (Vol 23 Section 11) Abbey Mills Pumping Station (Vol 25 Section 11)

Significance of effect	Receptor	Description of effect	Sites with significant effects (pre-mitigation)	Sites with significant residual effects
	Townscape character areas of medium sensitivity	Change to the character or setting of an area due to the presence of construction activity.	Carnwath Road Riverside (Vol 10 Section 11) Chelsea Embankment Foreshore (Vol 13 Section 11) Kirtling Street (Vol 14 Section 11) Heathwall Pumping Station (Vol 15 Section 11) Albert Embankment Foreshore (Vol 16 Section 11) Chambers Wharf (Vol 20 Section 11) King Edward Memorial Park Foreshore (Vol 21 Section 11) Earl Pumping Station (Vol 22 Section 11) Abbey Mills Pumping Station (Vol 25 Section 11) Minor work sites (Vol 27 Section 11)	Carnwath Road Riverside (Vol 10 Section 11) Chelsea Embankment Foreshore (Vol 13 Section 11) Kirtling Street (Vol 14 Section 11) Heathwall Pumping Station (Vol 15 Section 11) Albert Embankment Foreshore (Vol 16 Section 11) Chambers Wharf (Vol 20 Section 11) King Edward Memorial Park Foreshore (Vol 21 Section 11) Earl Pumping Station (Vol 22 Section 11) Abbey Mills Pumping Station (Vol 25 Section 11) Minor work sites (Vol 27 Section 11)
	Viewpoints of high sensitivity	Visibility of construction activity and/or plant, lighting, site welfare facilities etc	Acton Storm Tanks (Vol 4 Section 11) Hammersmith Pumping Station (Vol 5 Section 11) Barn Elms (Vol 6 Section 11) Putney Embankment Foreshore (Vol 7 Section 11) Dormay Street (Vol 8 Section 11) King George's Park (Vol 9 Section 11) Carnwath Road Riverside (Vol 10 Section 11) Falconbrook Pumping Station (Vol 11 Section 11)	Acton Storm Tanks (Vol 4 Section 11) Hammersmith Pumping Station (Vol 5 Section 11) Barn Elms (Vol 6 Section 11) Putney Embankment Foreshore (Vol 7 Section 11) Dormay Street (Vol 8 Section 11) King George's Park (Vol 9 Section 11) Carnwath Road Riverside (Vol 10 Section 11) Falconbrook Pumping Station (Vol 11 Section 11)

Significance of effect	Receptor	Description of effect	Sites with significant effects (pre-mitigation)	Sites with significant residual effects
			Cremorne Wharf Depot (Vol 12 Section 11) Chelsea Embankment Foreshore (Vol 13 Section 11) Kirtling Street (Vol 14 Section 11) Heathwall Pumping Station (Vol 15 Section 11) Albert Embankment Foreshore (Vol 16 Section 11) Victoria Embankment Foreshore (Vol 17 Section 11) Blackfriars Bridge Foreshore (Vol 18 Section 11) Shad Thames Pumping Station (Vol 19 Section 11) Chambers Wharf (Vol 20 Section 11) King Edward Memorial Park Foreshore (Vol 21 Section 11) Earl Pumping Station (Vol 22 Section 11) Deptford Church Street (Vol 23 Section 11) Greenwich Pumping Station (Vol 24 Section 11) Abbey Mills Pumping Station (Vol 25 Section 11) Minor work sites (Vol 27 Section 11)	Cremorne Wharf Depot (Vol 12 Section 11) Chelsea Embankment Foreshore (Vol 13 Section 11) Kirtling Street (Vol 14 Section 11) Heathwall Pumping Station (Vol 15 Section 11) Albert Embankment Foreshore (Vol 16 Section 11) Victoria Embankment Foreshore (Vol 17 Section 11) Blackfriars Bridge Foreshore (Vol 18 Section 11) Shad Thames Pumping Station (Vol 19 Section 11) Chambers Wharf (Vol 20 Section 11) King Edward Memorial Park Foreshore (Vol 21 Section 11) Earl Pumping Station (Vol 22 Section 11) Deptford Church Street (Vol 23 Section 11) Greenwich Pumping Station (Vol 24 Section 11) Abbey Mills Pumping Station (Vol 25 Section 11) Minor work sites (Vol 27 Section 11)
	Viewpoints of medium	Visibility of construction	Dormay Street (Vol 8 Section 11) King George's Park (Vol 9 Section 11)	Dormay Street (Vol 8 Section 11) King George's Park (Vol 9 Section 11)

Significance of effect	Receptor	Description of effect	Sites with significant effects (pre-mitigation)	Sites with significant residual effects
	sensitivity	activity and/or plant, lighting, site welfare facilities etc	Kirtling Street (Vol 14 Section 11) Heathwall Pumping Station (Vol 15 Section 11)	Kirtling Street (Vol 14 Section 11) Heathwall Pumping Station (Vol 15 Section 11)
	Viewpoints of low sensitivity	Visibility of construction activity and/or plant, lighting, site welfare facilities etc	Blackfriars Bridge Foreshore (Vol 18 Section 11)	Blackfriars Bridge Foreshore (Vol 18 Section 11)
Operation – adverse	Townscape character areas of high sensitivity	Change to the character or setting of an area due to the presence of the proposed development.	Chelsea Embankment Foreshore (Vol 13 Section 11)	Chelsea Embankment Foreshore (Vol 13 Section 11)
	Viewpoints of high sensitivity	Visibility of operational development e.g. new public realm, tree planting, above ground structures, lighting and landscape design for the site	Chelsea Embankment Foreshore (Vol 13 Section 11)	Chelsea Embankment Foreshore (Vol 13 Section 11)

Significance of effect	Receptor	Description of effect	Sites with significant effects (pre-mitigation)	Sites with significant residual effects
Operation – beneficial	Townscape character areas of high sensitivity	Change to the character or setting of an area due to the presence of the proposed development.	King Edward Memorial Park Foreshore (Vol 21 Section 11) Deptford Church Street (by Year 15 of operation) (Vol 23 Section 11)	King Edward Memorial Park Foreshore (Vol 21 Section 11) Deptford Church Street (by Year 15 of operation) (Vol 23 Section 11)
	Townscape character areas of medium sensitivity	Change to the character or setting of an area due to the presence of the proposed development.	Carnwath Road Riverside (Vol 10 Section 11) Albert Embankment Foreshore (Vol 16 Section 11)	Carnwath Road Riverside (Vol 10 Section 11) Albert Embankment Foreshore (Vol 16 Section 11)
	Viewpoints of high sensitivity	Visibility of operational development e.g. new public realm, tree planting, above ground structures, lighting and landscape design for the site	Acton Storm Tanks (Vol 4 Section 11) Carnwath Road Riverside (by Year 15 of operation) (Vol 10 Section 11) Falconbrook Pumping Station (summer only) (Vol 11 Section 11) Albert Embankment Foreshore (Vol 16 Section 11) Chambers Wharf (Vol 20 Section 11) King Edward Memorial Park Foreshore (Vol 21 Section 11) Earl Pumping Station (Vol 22 Section 11) Deptford Church Street (by Year 15 of operation) (Vol 23 Section 11)	Acton Storm Tanks (Vol 4 Section 11) Carnwath Road Riverside (by Year 15 of operation) (Vol 10 Section 11) Falconbrook Pumping Station (summer only) (Vol 11 Section 11) Albert Embankment Foreshore (Vol 16 Section 11) Chambers Wharf (Vol 20 Section 11) King Edward Memorial Park Foreshore (Vol 21 Section 11) Earl Pumping Station (Vol 22 Section 11) Deptford Church Street (by Year 15 of operation) (Vol 23 Section 11)

Significance of effect	Receptor	Description of effect	Sites with significant effects (pre-mitigation)	Sites with significant residual effects
	Viewpoints of medium sensitivity	Visibility of operational development e.g. new public realm, tree planting, above ground structures, lighting and landscape design for the site	Heathwall Pumping Station (summer only) (Vol 15 Section 11)	Heathwall Pumping Station (summer only) (Vol 15 Section 11)

Thames Tideway Tunnel
Thames Water Utilities Limited

Application for Development Consent

Application Reference Number: WWO10001

Environmental Statement

Doc Ref: **6.2.03**

Volume 3: Project-wide effects assessment

Section 12: Transport

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

Hard copy available in

Box **17** Folder **A**
January 2013

Thames Tideway Tunnel
Creating a cleaner, healthier River Thames

This page is intentionally blank

Thames Tideway Tunnel

Environmental Statement

Volume 3: Project-wide effects assessment

Section 12: Transport

List of contents

Page number

List of plates

Page number

List of tables

Page number

This page is intentionally blank

12 Transport

12.1 Introduction

12.1.1 This section presents the findings of the assessment of the likely significant project-wide effects on transport. This covers the effects arising at a strategic level from the combined construction worker and vehicle movements from all Thames Tideway Tunnel project sites. It also examines a sub-area of central London along Victoria Embankment (A3211) where concurrent construction work on adjacent Thames Tideway Tunnel project sites may produce particular effects in that sub-area.

12.1.2 The effects at the local level around individual sites are described in Section 12 of Vols 4 to 27.

12.1.3 At the project-wide level, construction of the proposed development has the potential to affect the following transport elements:

a. public transport patronage

b. river movements

c. highway network operation.

12.1.4 Effects on each of these elements are considered within this assessment for the construction phase of the project as a whole.

12.1.5 Operational project-wide effects for transport have not been assessed. This is on the basis that maintenance trips to the Thames Tideway Tunnel project sites would be infrequent, short-term and localised, no significant project-wide operational effects are considered likely.

12.1.6 The *Environmental Statement* presents the information which supports the assessment of transport effects and the findings of the assessment. Additionally, a separate *Transport Assessment* has been produced which provides further technical and background information supporting the assessment of the effects on the transport network as a result of the construction phase of the project.. The *Transport Assessment* accompanies the application for development consent (the 'application').

12.1.7 Relevant plans and figures for the project-wide assessment are contained in a separate volume (Vol 3 Project-wide effects assessment Figures).

12.2 Proposed development relevant to transport

12.2.1 The proposed development is described in Section 3 of this volume, with further details of each site described in Section 3 of Vols 4 to 27. The elements of the proposed development relevant to transport are set out below.

Construction

12.2.2 The proposed development consists of 24 construction sites situated across 13 London local authorities. Each worksite has its own local characteristics, which are discussed in the site-specific assessments in Vols 4 to 27.

12.2.3 The construction proposals would influence vehicle and personnel movement demands through a combination of:

a. the permanent design works scope and requirements to deliver the overall project objectives

b. construction programme, which would influence the profile of movement demands in time both for individual sites and for the project overall

c. the construction site methodology, including the works to be undertaken at each site, which would influence the number of personnel required at each location, the volumes of material and the extent of plant and equipment (and thus construction traffic) that are expected

d. the *Transport Strategy*, which accompanies the application, including the degree to which the river may be used to transport materials to and from certain sites, which would directly influence the numbers of construction vehicles and vessels associated with construction at each site.

Construction programme

12.2.4 For the purposes of the assessment, the estimated start date for the overall construction programme is in early 2016 and construction would last for just under seven years, finishing towards the end of 2022.

12.2.5 Within this section, assessment years have been referred to as 'Project Years' which are measured in 12 month periods from the beginning of construction work on the project as a whole.

12.2.6 Construction programmes at individual sites would vary within this overall programme and therefore peak construction activity would not occur at the same time on all sites. The estimated programme for each site is set out in Section 3 of Vols 4-27.

Material quantities

12.2.7 The amount of construction material to be imported to and exported from each site would vary depending on the nature of the construction activity to be undertaken in each location.

12.2.8 Vol 3 Figure 12.2.1 (see separate volume of figures) summarises the total volumes of material to be transported at each site across the construction programme. It also indicates whether each site has the potential for access to and from the river for the transport of construction material.

12.2.9 Vol 3 Figure 12.2.1 (see separate volume of figures) shows that the sites generating the highest tonnages would be Carnwath Road Riverside, Kirtling Street and Chambers Wharf, which would be the three main tunnel drive sites for the project.

12.2.10 Construction of the project would require the following types of material:

a. exported site excavated material from the tunnels, shafts and other works

b. imported and exported cofferdam fill material

c. exported demolition material

d. imported concrete (either ready mixed prior to arrival at the site or prepared on site at a batching plant; through the delivery of aggregates, sand and cement)

e. imported grout materials

f. imported steel reinforcement

g. imported shaft and tunnel segments (pre-cast concrete)

h. imported tunnel supplies and consumables (formwork/pipe/track/oils)

i. imported and exported construction plant and equipment

j. imported site office consumables.

12.2.11 The greatest proportion of material generated by the project would be excavated material, with approximately 4.7 million tonnes generated over the course of the project across all worksites. This equates to approximately 59% of the total tonnage.

12.2.12 The other main material types required for the project are concrete (ready mix or raw materials for on-site batching, 13.7% of total tonnage), imported fill (8.2%) and tunnel segments (7.7%).

Transport Strategy

12.2.13 The proposed *Transport Strategy*, which accompanies the application, has been developed by considering a range of issues relating to the potential for construction materials to be transported by road, river and rail.

12.2.14 A wide range of criteria have been examined which include consideration of the various transport options in terms of:

a. policy and policy drivers

b. economic, environmental and social impacts of each transport option

c. practicality and risk in the context of the Thames Tideway Tunnel project

d. safety

e. cost.

12.2.15 During the development of the *Transport Strategy*, key stakeholders including Transport for London (TfL), the Greater London Authority (GLA), the Port of London Authority (PLA) and the relevant London boroughs were consulted and participated in a series of workshops.

12.2.16 The proposed *Transport Strategy* takes account of opportunities to:

a. reduce the need to transport materials and waste to and from worksites

b. increase use of river and rail modes where these were judged to provide the best environmental outcomes balanced against the need to be practicable and cost effective

c. adopt best practice within project planning to reduce the number of trips, such as considering the use of local sources for materials and disposal

d. adopt best practice techniques to reduce fuel consumption and emissions and to reduce the risk of accidents, including participation in relevant London schemes such as the TfL Freight Operator Recognition Scheme (FORS).

12.2.17 Detailed consideration has been given to the issues associated with moving each type of construction material by different modes, the operational constraints at each site and the characteristics of the relevant supply chains.

12.2.18 The proposed *Transport Strategy* is summarised in Vol 3 Table 12.2.1 and is based on the following materials being transported by river:

a. main tunnel excavated material from the main tunnel drive sites at Carnwath Road Riverside, Kirtling Street and Chambers Wharf

b. import and export of cofferdam fill material at Putney Embankment Foreshore, Chelsea Embankment Foreshore, Heathwall Pumping Station, Albert Embankment Foreshore, Victoria Embankment Foreshore, Blackfriars Bridge Foreshore, Chambers Wharf and King Edward Memorial Park Foreshore

c. shaft excavated material from Putney Embankment Foreshore, Carnwath Road Riverside, Cremorne Wharf Depot, Chelsea Embankment Foreshore, Heathwall Pumping Station, Albert Embankment Foreshore, Victoria Embankment Foreshore, Blackfriars Bridge Foreshore, Chambers Wharf and King Edward Memorial Park Foreshore

d. excavated material from connection tunnels, interception and associated structures at Putney Embankment Foreshore, Cremorne Wharf Depot, Chelsea Embankment Foreshore, Albert Embankment Foreshore, Victoria Embankment Foreshore, Blackfriars Bridge Foreshore, Chambers Wharf and King Edward Memorial Park Foreshore

e. import of sand and aggregates for main tunnel secondary lining for the main tunnel drive sites at Carnwath Road Riverside, Kirtling Street and Chambers Wharf.

12.2.19 For the environmental impact assessment (EIA) it has been assumed that 90% of these materials would be transported by river. This allows for the possibility that there may be short periods during which river transport is unavailable because of temporary navigational or other constraints or because material is unsuitable for river transport. Based on this assumption, the *Transport Strategy* equates to approximately 53% of the total tonnage of construction materials being transported by river across the construction period.

12.2.20 A sensitivity test to consider the possibility of variation in construction vehicle numbers has been considered in the Vol 3 Appendix J.

Vol 3 Table 12.2.1 Transport – materials transport by river

Construction site	Cofferdam fill (import / export)	Shaft excavated material (export)	Main tunnel excavated material (export)	Other excavated material (export)	Main tunnel secondary lining aggregates (import)
Putney Embankment Foreshore	Y	Y	n/a	Y	n/a
Carnwath Road Riverside	n/a	Y	Y	n/a	Y
Cremorne Wharf Depot	n/a	Y	n/a	Y	n/a
Chelsea Embankment Foreshore	Y	Y	n/a	Y	n/a
Kirtling Street	n/a	n/a*	Y	n/a	Y
Heathwall Pumping Station	Y	Y	n/a	n/a	n/a
Albert Embankment Foreshore	Y	Y	n/a	Y	n/a
Victoria Embankment Foreshore	Y	Y	n/a	Y	n/a
Blackfriars Bridge Foreshore	Y	Y	n/a	Y	n/a
Chambers Wharf	Y	Y	Y	Y	Y
King Edward Memorial Park Foreshore	Y	Y	n/a	Y	n/a

Note: the Transport Strategy which accompanies the application assumes that 90% of the materials indicated above would be transported by river from the sites indicated.

** Programme constraints preclude the transport of main tunnel shaft excavation materials being proposed by river at Kirtling Street.*

Construction lorry and barge numbers

12.2.21 The anticipated total numbers of construction lorries and barges visiting the construction sites are presented in Vol 3 Table 12.2.2.

12.2.22 The assessment has been based on a range of scenarios which represent the months of peak cumulative activity for sites in the western, central and eastern sections of the project and for the project as a whole. Section 12.5 explains how these scenarios have been derived and presents the relevant construction lorry and barge numbers for them.

Vol 3 Table 12.2.2 Transport – construction lorry and barge details (whole project)

Construction site	Total number of construction lorries		Total number of construction barges	
	Lorries	Movements	Barges	Movements
Acton Storm Tanks	5,920	11,840	0	0
Hammersmith Pumping Station	5,270	10,540	0	0
Barn Elms	3,360	6,720	0	0
Putney Embankment Foreshore	3,330	6,660	167	334
Carnwath Road Riverside	25,850	51,700	1,067	2,134
Dormay Street	5,300	10,600	0	0
King Georges Park	2,020	4,040	0	0
Falconbrook Pumping Station	3,740	7,480	0	0
Cremorne Wharf Depot	3,340	6,680	56	112
Chelsea Embankment Foreshore	5,600	11,200	209	418
Kirtling Street	51,520	103,040	1,620	3,240
Heathwall Pumping Station	4,230	8,460	137	274
Albert Embankment Foreshore	6,650	13,300	581	1,162
Victoria Embankment Foreshore	5,750	11,500	144	288
Blackfriars Bridge Foreshore	13,350	26,700	369	738
Chambers Wharf	32,350	64,700	834	1,668
Shad Thames Pumping Station	1,020	2,040	0	0

Construction site	Total number of construction lorries		Total number of construction barges	
	Lorries	Movements	Barges	Movements
King Edward Memorial Park Foreshore	10,610	21,220	186	372
Bekesbourne Street	340	680	0	0
Earl Pumping Station	9,110	18,220	0	0
Deptford Church Street	8,700	17,400	0	0
Greenwich Pumping Station	32,320	64,640	0	0
Abbey Mills Pumping Station	17,350	34,700	0	0
Beckton Sewage Treatment Works	8,590	17,180	0	0
TOTAL	265,620	531,240	5,372	10,744

12.2.23 Construction vehicle movements would take place during the typical day shift of ten hours on weekdays (08:00 to 18:00) and five hours on Saturdays (08:00 to 13:00).

12.2.24 It is only in exceptional circumstances that HGV and abnormal load movements could occur up to 22:00 on weekdays for large concrete pours and later at night by agreement with the relevant local planning authority.

Lorry and barge types

12.2.25 Vol 3 Table 12.2.3 below summarises the road vehicle types required in order to transport each material type by road.

Vol 3 Table 12.2.3 Transport – construction lorry types

Vehicle type	Material
Rigid-bodied vehicle	Excavation, fill (in and out), sand and aggregates for concrete, ready mix concrete, demolition material, reinforcement bar (rebar), office supplies
Articulated vehicle	Tunnel linings, cement for concrete, grout supplies (sand/filler, bentonite, fly ash, cement), rebar, structural steel, office supplies, TBM supplies, plant and equipment

12.2.26 Vol 3 Table 12.2.4 shows the barge sizes assumed at each construction site where materials would be transported by river. This is based on consultation with the PLA and assessment of the site arrangements, river conditions at the site and the nature of the materials to be transported by barge.

Vol 3 Table 12.2.4 Transport – barge sizes

Site name	Excavated material (T)	Imported cofferdam fill (T)	Bulk aggregates (T)
Putney Embankment Foreshore	350	350	n/a
Carnwath Road Riverside	800	n/a	350
Cremorne Wharf Depot	350	n/a	n/a
Chelsea Embankment Foreshore	800	800	n/a
Kirtling Street	1000	n/a	350
Heathwall Pumping Station	350	350	n/a
Albert Embankment Foreshore	350	350	n/a
Victoria Embankment Foreshore	800	800	n/a
Blackfriars Bridge Foreshore	800	800	n/a
Chambers Wharf	1500	1000	350
King Edward Memorial Park Foreshore	1000	1000	n/a

Construction traffic routing

12.2.27 The routes that would be used by road-based construction traffic serving the Thames Tideway Tunnel project sites have been determined from consideration of a number of key issues. These include the supply and disposal locations to and from which construction vehicles would travel and the nature of the highway network on those routes.

12.2.28 A review of likely supplier locations and disposal sites has been undertaken. Vol 3 Figure 12.2.2 (see separate volume of figures) shows the range of locations of potential supplier sites within London and the surrounding area.

12.2.29 No firm decisions have been made about which of these sites would be used but the review was intended to provide informative representative sample of general locations that might be used to support the assignment of construction traffic to the transport networks.

12.2.30 Vol 3 Figure 12.2.3 (see separate volume of figures) shows the proposed network of construction routes to be used by project construction traffic.

Construction workers

12.2.31 In total, the Thames Tideway Tunnel project construction sites are expected to require a maximum workforce of 2,288 workers on site each day[i]. However, not all workers would be on site at the same time of day (because some sites would require shift working). Vol 3 Table 12.2.5 summarises the number of workers estimated to be required at each site and shows that the total number of workers present during the dayshift would be 1,637 workers.

Vol 3 Table 12.2.5 Transport – maximum estimated construction worker numbers

Site	Total workers	Dayshift workers
Acton Storm Tanks	40	40
Hammersmith Pumping Station	45	45
Barn Elms	40	40
Putney Embankment Foreshore	50	50
Carnwath Road Riverside	289	165
Dormay Street	92	45
King Georges Park	40	40
Falconbrook Pumping Station	40	40
Cremorne Wharf Depot	65	65
Chelsea Embankment Foreshore	65	65
Kirtling Street	426	235
Heathwall Pumping Station	40	40
Albert Embankment Foreshore	65	65
Victoria Embankment Foreshore	65	65
Blackfriars Bridge Foreshore	70	70
Chambers Wharf	289	165
Shad Thames Pumping Station	24	24
King Edward Memorial Park Foreshore	40	40
Bekesbourne Street	24	24

[i] This estimate is based on a build-up of the likely construction skills and trades required at each worksite. It does not include the off-site workforce, eg river transport, segment manufacturing or office based staff. The total amount of construction work created by the project, over the whole construction period, is estimated to be approximately 19,200 man years which at its peak is estimated to equate to approximately 4,250 jobs.

Site	Total workers	Dayshift workers
Earl Pumping Station	40	40
Deptford Church Street	40	40
Greenwich Pumping Station	289	165
Abbey Mills Pumping Station	45	45
Beckton Sewage Treatment Works	65	24
TOTAL	2,288	1,637

Dayshift workers represents the maximum number of workers on site at any one time.

12.2.32 The assumed mode shares of worker journeys are described in more detail in Section 12.5 and the methodology for assigning worker trips to the transport networks is described in Volume 2 Environmental assessment methodology Section 12.

Code of Construction Practice

12.2.33 Measures incorporated into the *Code of Construction Practice (CoCP)*[ii] *Part A* (Section 5) (see Vol 1 Appendix A) to reduce transport impacts include:

a. contractors would ensure that works are undertaken in such a way as to maintain existing public access routes and rights of way, as far as is reasonably practicable

b. where required alternative or diverted routes would be adequately signed

c. the transportation of materials, including hazardous materials, would consider the risk of pollution incidents and include mitigation measures to reduce the likelihood and impact of any incident

d. a site-specific *Traffic Management Plan* would be prepared for each site in consultation with the highway authorities and the emergency services and agreed with those organisations. This would include arrangements for site access and egress, temporary and permanent changes to highways, the strategy for traffic management and parking management and agreement on the local routes to be used by construction lorries. A *Construction and Logistics Plan* would also be prepared detailing the management of movements to and from the site

e. provision to maintain access for deliveries to neighbouring properties and to inform occupiers of proposed closures and diversions in advance

[ii] The *Code of Construction Practice (CoCP)* is provided in Vol1 Appendix A. It contains general requirements (Part A) and site-specific requirements (Part B).

f. lorry management measures including approved routes for lorries, arrangements to ensure that lorries do not arrive before standard working hours or park or wait in non-agreed areas and a system of pre-notification of vehicle arrivals to prevent queuing outside sites

g. a requirement for contractors to minimise the need for and duration of diversions to pedestrian, cycle and vehicle routes, to provide clear signage of diversions, ensure they are suitable for mobility-impaired users where practicable and provide controls at site accesses to ensure the safety of pedestrians and cyclists

h. the adoption of best practice measures for construction road transport, such as the use of vehicles compliant with EURO 5 emission standards, vehicles to be fitted with 'active' cycle safety measures and membership of the TfL Freight Operator Recognition Scheme (FORS).

12.2.34 Where river transport would to be used for construction materials, the *CoCP Part A* includes provisions for the following:

a. contractors would be required to maintain existing navigational channels and undertake works so as to limit undue inconvenience to the public and river users as far as is reasonably practicable

b. a site-specific *River transport management plan* would be produced for each relevant construction site, in consultation with the Port of London Authority (PLA), Maritime and Coastguard Agency (MCA) and the emergency services, together with other river users and operators. These Plans would include defined roles and responsibilities for activities associated with river transportation, dredging arrangements, an agreed standard operating methodology and emergency arrangements and contingency plans.

12.2.35 The implementation of these measures has been assumed for the assessment of construction effects.

12.2.36 Based on current travel planning guidance including TfL's 'Travel planning for new development in London (TfL, 2011)[1] this development lies within the threshold for producing a Strategic Framework Travel Plan. A *Draft Project Framework Travel Plan* has been prepared based on the TfL ATTrBuTE guidance[2]. The *Draft Project Framework Travel Plan*, which accompanies the application, addresses project-wide travel planning measures, including the need for a Travel Plan Manager, initial travel surveys during construction and a monitoring framework. It also contains requirements and guidelines for the development of site-specific *Travel plans* by the appointed contractors.

12.2.37 The *Draft Project Framework Travel Plan* sets out:

a. the overarching objectives for travel planning for the project

b. project-wide targets in the context of which site-specific targets would be developed

c. an outline of the indicators that may be used to monitor *Travel plan* progress, which would be developed further as necessary during the life of the *Travel plan*

d. the proposed management structure for the *Project Framework Travel Plan* and site-specific *Travel plans* and the relationships between them, including arrangements for a Travel Plan Liaison Group

e. the responsibilities of the client, contractor, subcontractors and workers in relation to the *Travel plans*

f. the types of travel planning measures that may be appropriate for this project

g. requirements for ongoing monitoring and review of the *Travel plans* on a regular basis, through employee travel surveys and engagement with the Travel Plan Liaison Group.

12.3 Assessment methodology

12.3.1 The general methodology for preparing the project-wide assessment is described in Vol 2 Section 12. Specific details of the methodology used for the project-wide assessment are provided below.

Stakeholder engagement

12.3.2 Vol 2 documents the overall engagement which has been undertaken in preparing the *Environmental Statement*. This includes general comments on the transport assessment methodology, including that for the methodology relating to the project-wide assessment of effects on transport.

Baseline

12.3.3 The baseline methodology for the project-wide assessment is concerned only with identifying baseline conditions in terms of the public transport, river and highway networks.

12.3.4 Changes to the pedestrian and cycle networks and additional walking and cycling trips arising from the project would be most evident, and have the greatest effects, in the immediate surroundings of each site. They have therefore been assessed at the site-specific level and the outcomes are reported in Section 12 of Vols 4 to 27. Consequently, no detailed project-wide baseline information is required for the project-wide assessment.

12.3.5 Similarly, journeys made by workers on public transport are most likely to present effects on the networks and services in the vicinity of each of the Thames Tideway Tunnel construction sites. Vols 4 to 27 assess these site-specific effects and include baseline information on the public transport services available at each location.

12.3.6 Given that the number of worker journeys by public transport at the majority of sites would be low compared to the number of journeys already being made on the wider network, and that these worker journeys would be dispersed across London, it is not necessary to undertake a detailed quantitative analysis of the operation of the public transport networks at a project-wide level. Additional baseline data for public transport at a project-wide level is therefore not required.

12.3.7 Traffic flow data collection has been undertaken in the vicinity of all of the proposed Thames Tideway Tunnel construction sites to inform the site-specific assessments. At the project-wide level, it has not been necessary to carry out project-wide traffic data collection as the assessment draws on existing strategic highway models developed by TfL, as explained in para. 12.3.17.

Construction

12.3.8 As discussed in Vol 2 Section 12, the assessment examines the likely significant construction effects of the project on transport at three levels:

a. a project-wide assessment: this identifies the impacts associated with all Thames Tideway Tunnel project construction sites within the project, which is contained in this section of Vol 3

b. an assessment of a sub-area of central London around the Victoria Embankment Foreshore and Blackfriars Bridge Foreshore sites to examine the effects arising from concurrent construction activity at those sites. This sub-area assessment is contained in this section of Vol 3

c. site-specific assessments: these identify the impacts local to each of the individual sites. These assessments are contained within the site-specific assessment Section 12 of Vols 4 to 27.

12.3.9 The assessment methodology for the construction phase for the project-wide assessment follows that described in Vol 2 Section 12. As set out in para. 12.1.3, the project-wide assessment considers the effects on three transport elements; public transport patronage, river movements and highway network operation.

12.3.10 Effects on public transport networks are most likely to be experienced in the areas surrounding each of the construction sites and on the routes serving those sites. These effects have been assessed in Section 12 of Vols 4 to 27.

12.3.11 At the project-wide level, therefore, only a broad assessment of effects on public transport service patronage has been made based on comparison of the number of public transport journeys expected to arise from the project with the overall density and use of the public transport network in Greater London. The significance of project-wide effects is based on this comparison and is related to the typical capacities of different public transport services, to provide context, rather than on a detailed quantitative analysis of overall public transport network capacity. This is considered appropriate because the number of worker journeys by public transport would be very low compared to existing passenger volumes on the network as a whole.

12.3.12 The assessment also recognises that bus services may be affected by changes occurring on the highway network as a result of the construction of the Thames Tideway Tunnel. Where relevant, this has been taken into account in the site-specific assessments in determining the significance of effects on bus services.

12.3.13 The project-wide effects of additional barge movements on the River Thames have been assessed by comparison with the estimated number of barge movements occurring on the river in the construction base case. Site-specific issues are addressed in Section 12 of Vols 4 to 27.

12.3.14 For the project-wide assessment, consideration has been given to the number of river transit movements required to move the anticipated number of construction barges. This takes account of the fact that barges would be hauled by tugs and that smaller barges may be capable of being hauled in pairs, subject to mooring and tidal conditions. Each individual barge may not therefore require a separate river transit movement. This is explained further in para. 12.5.38.

12.3.15 Additionally, the assessment has examined how the number of construction-related river movements would change along the length of the River Thames. The assessment therefore examines the point at which the number of movements would move from one impact magnitude threshold to another, based on the criteria set out in Vol 2 Section 12. The significance of effects therefore varies along the length of the river, in line with the variation in the anticipated number of construction-related river movements.

12.3.16 Separate navigational issues and preliminary risk assessments have been undertaken and are reported separately in the *Navigational Issues and Preliminary Risk Assessments* report that accompanies the application.

12.3.17 For the assessment of the highway network, the TfL Highway Assignment Models (HAMs)[iii] have been used, as described in Vol 2 Section 12. These are strategic models which cover large areas of London's highway network which have been developed by TfL as a tool for modelling strategic changes in traffic flow and capacity, particularly in relation to future development, employment and population change.

12.3.18 The HAMs represent peak hours of 08:00 to 09:00 and 17:00 to 18:00 and these have been taken as being the network-wide AM and PM peak hours in the project-wide and site-specific assessments.

12.3.19 The assignment of construction lorry and construction site operational traffic to the network has been undertaken using the OmniTrans software package[iv]. This has enabled traffic to be correctly assigned to the proposed construction routes across the London highway network. This ensures that the model shows such traffic being limited to those routes and does not seek to dynamically reassign construction lorries to other routes which are less suitable. Any dynamic reassignment of traffic that occurs in the construction development case models therefore represents existing (base case) journeys diverting onto alternative routes.

[iii] The TfL Highway Assignment Models used in the assessment are the West London Highway Assignment Model (WeLHAM), the Central London Highway Assignment Model (CLoHAM) and the East London Highway Assignment Model (ELHAM), all of which use the SATURN strategic highway network modelling software.

[iv] OmniTrans is a software package used for multi-modal transport network modelling and in this case has been used to produce assignments of construction traffic across the proposed network of routes to be used for the project.

12.3.20 The routes for construction lorry trips were allocated to fixed routes defined for each origin / destination pair. The proposed routes were discussed and refined with TfL and the LHAs. The routes were identified using the following criteria:

a. using the most appropriate route from the site to the Strategic Road Network (SRN) / Transport for London Road Network (TLRN)

b. keeping to the SRN / TLRN where possible and minimising use of lower class roads

c. avoiding routes with height / weight / width restrictions and banned turns

d. avoiding, where possible, heavily congested routes.

12.3.21 The fixed routes have been coded into SATURN as pre-loaded fixed flows, using a passenger car unit (pcu) factor of two for HGVs, which means that each additional construction HGV movement contributes to the delay on a link it uses to the equivalent of two additional car movements.

12.3.22 Section 12.5 explains the assumptions made about worker car journeys for the purposes of the assessment and that this represents a robust analysis. At this stage the resident addresses of workers are not known and workers may be travelling from within or outside the Greater London area. It has therefore been assumed that the origins of worker car trips, where they might arise, would be similar to the origins of trips made to the zones within the HAMs within which each project site is located.

12.3.23 As the number of worker car trips would be low in comparison to the number of individual zones on the TfL HAMs, the distribution of existing journeys in the HAMs has been sectored to the borough level and worker car trips have been assigned to the model on this basis. Within the HAMs, it has been assumed that workers travelling by car would be free to choose the most appropriate routes to and from the site based on network conditions.

12.3.24 The HAMs have been developed by TfL using GLA employment and population forecasts, which are based on the employment and housing projections set out in the London Plan (GLA, 2011)[3]. As a result the HAMs and therefore the assessment inherently take into account a level of future growth and development across London within the project-wide base case traffic flows. There are no construction cumulative effects requiring assessment.

12.3.25 Additionally, it is noted that changes that would be created to the highway network during construction, which could affect network operation, have been included in the construction development case models. These occur at two locations:

a. Blackfriars Bridge Foreshore, where the westbound slip road from Blackfriars Bridge Road (A201) to Victoria Embankment (A3211) would be closed for part of the construction works

b. Deptford Church Street, where the northbound carriageway of Deptford Church Street (A2209) would be closed for part of the construction works and single lane contraflow working would be introduced on the southbound carriageway.

12.3.26 For the project-wide assessment, the impact criteria set out in Vol 2 Section 12 have been considered, although there are slight variations to the way in which they are used compared to the site-specific assessments.

12.3.27 In considering road network delay issues, an overall comparison has been made between the construction base and development cases using the summary model statistics generated from the HAMs. This includes information on time associated with all delays in the model network and the average speed of traffic within the modelled area. This provides an overview of the degree of change likely to be experienced at a strategic level as a result of the additional construction traffic from the project.

12.3.28 The models have also been interrogated to identify where changes in delay would occur on links or at junctions within the modelled network, which would be within the thresholds set out in the impact magnitude criteria in Vol 2 Section 12. Locations where changes in delay of less than one minute on a route would occur (which represents a negligible impact using the criteria in Vol 2 Section 12) have been filtered out to simplify the reporting of the assessment within Section 12.5.

12.3.29 Accidents and safety issues at a project-wide level have been assessed by considering, in broad terms, the number of additional lorry miles associated with Thames Tideway Tunnel project construction traffic and comparing this with London-wide accident rates from published statistics. This provides an overview of the potential change in accident risk, which has been placed in the context of the reported accident statistics across London in order to form a judgement on the project-wide effects on accidents. The site-specific assessments address the effects on accidents and safety in each of the project site locations.

12.3.30 There would be deliveries of fuel for construction plant to the Thames Tideway Tunnel sites and a number of construction products may be classified as hazardous. Hazardous load movements would be distributed across the London highway network and the effects of hazardous loads in the vicinity of individual sites are addressed in the site-specific assessments. Because of this distribution of hazardous loads across the wider network, it is not appropriate to simply aggregate the number of hazardous load movements and apply the criteria set out in Vol 2 Section 12 in order to determine project-wide effects as this would lead to effects being overstated. The project-wide assessment therefore considers the effects reported in Section 12 of Vols 4 to 27 for each of the sites and draws an overall conclusion based on the typical range of significance identified across all sites.

Construction assessment area

12.3.31 As described above, for the project-wide highway network assessment, strategic modelling has been undertaken using the TfL HAMs. These comprise five strategic models. Three of these models have been used in this assessment and their scope is shown in Vol 3 Figure 12.3.1, Vol 3 Figure 12.3.2 and Vol 3 Figure 12.3.3 (see separate volume of figures):

a. the West London Highway Assignment Model (WeLHAM)

b. the Central London Highway Assignment Model (CLoHAM)

c. the East London Highway Assignment Model (ELHAM).

12.3.32 These three models between them cover the full extent of the route of the Thames Tideway Tunnel project and the majority of the routes that are expected to be used by construction traffic. Their use for the assessment has been agreed with TfL and it has also been agreed that the remaining two HAMs (the North London and South London HAMs) do not need to be used. Vol 3 Figure 12.3.4 (see separate volume of figures) shows how schematically how the construction sites are located relative to the boundaries of each of the three HAMs used in the assessment.

Construction assessment years

12.3.33 The effects on the public transport network in the construction phase have been assessed for the same period as for the highway network assessment, which is discussed in paras. 12.3.35 to 12.3.42 below.

12.3.34 The assessment of the effects on river movement is based on the month in which the cumulative number of barge movements from all sites would be greatest. This would occur in Project Year 2 of construction.

12.3.35 The HAMs used for the project-wide highway network assessment have been constructed by TfL to represent a base year of 2008 / 2009. For this assessment, these 2008 / 2009 have been taken as being equivalent to baseline conditions. The HAMs have a forecast year of 2021, which has been adopted as the construction base case for this assessment.

12.3.36 Given that the effects of the project have been identified in relation to the construction base case, rather than to baseline conditions, the assessment has not undertaken any additional strategic level modelling of the highway network for the baseline situation. Instead, the outputs from the 2008 / 2009 modelled base year in the HAMs have been used, as explained in para. 12.3.35.

12.3.37 To assess the project-wide effects on the highway network, four assessment scenarios have been considered.

12.3.38 Firstly, the estimated profile of construction traffic for each of the sites has been combined to produce a project-wide profile on a month-by month basis. This is shown on Vol 3 Plate 12.3.1.

Vol 3 Plate 12.3.1 Transport – average daily construction lorry movements, whole project

12.3.39 Vol 3 Plate 12.3.1 shows that the highest aggregate average number of daily construction vehicle movements across the project would occur in Project Year 4 of construction. This has been adopted as the 'project-wide peak' scenario for the strategic highway assessment.

12.3.40 In addition to the project-wide peak scenario, the estimated construction profiles for the sites in each of the three HAM areas (WeLHAM, CLoHAM and ELHAM as shown in Vol 3 Figures 12.3.1, 12.3.2 and 12.3.3 (see separate volumes of figures) have been combined to determine when the highest aggregate average daily construction movements would occur in each of the HAM areas. This has produced three 'cluster peak' scenarios. The three 'cluster peaks' would occur in Project Year 2 of construction (western cluster) and Project Year 4 of construction (central and eastern cluster).

12.3.41 Each cluster peak has been tested using the relevant HAM (for example, the western cluster peak has been tested using WeLHAM as that is the scenario in which traffic arising from sites within that model would be greatest). In each case the cluster peak scenarios include traffic that would be generated from all Thames Tideway Tunnel project sites in the relevant cluster peak month. This means that any traffic associated with sites in a different cluster, but which passes through the cluster area being assessed, has been included in the assessment.

12.3.42 As noted in Vol 2 Section 12, the construction traffic generated in the project-wide and cluster peak scenarios has been added to the 2021 forecast year in the relevant HAM(s). It has been agreed with TfL that this would represent the addition of construction traffic to the construction base case, in order to maintain consistency between this assessment and the work already undertaken by TfL in the HAMs.

Sub-area analysis

12.3.43 In addition to the strategic modelling work to examine the effects across the west, central and east London road networks, a specific assessment has been undertaken to examine the operation of the highway network in a sub-area of central London.

12.3.44 This responds to requests from stakeholders to consider the effects on the highway network that might result from construction at the Victoria Embankment Foreshore and Blackfriars Bridge Foreshore sites taking place at the same time. These sites would both involve traffic management changes on the Embankment route and stakeholders have asked for the sub-area assessment to determine whether the interaction of these works would present any effects on the operation of that part of the highway network.

12.3.45 It has been agreed with TfL that the appropriate tool for this sub-area assessment is a VISSIM[v] traffic micro-simulation model. This permits analysis in more detail than the TfL HAMs, whilst also allowing a number of junctions within a network to be included within the same model.

VISSIM assessment area

12.3.46 Victoria Embankment Foreshore and Blackfriars Bridge Foreshore would be located approximately 1.5km apart along Victoria Embankment (A3211), and it is acknowledged that there is a possibility that concurrent works at both sites could affect conditions on that stretch of Victoria Embankment (A3211).

12.3.47 The Chelsea Embankment Foreshore site would be a further 4.5km to the west of the Victoria Embankment Foreshore site and it is therefore considered unlikely that any interaction on traffic conditions would occur. The effects of construction at Chelsea Embankment Foreshore are most likely to be evident in the immediate area rather than further to the east on Victoria Embankment (A3211). Those effects have been assessed in Section 12 of Vol 13.

12.3.48 The sub-area analysis therefore addresses the potential effects that could arise on Victoria Embankment (A3211) as a result of construction activity at the Victoria Embankment Foreshore and Blackfriars Bridge Foreshore sites.

12.3.49 The assessment area for the VISSIM model extends along Victoria Embankment (A3211) from Westminster Bridge (A302) in the west to Blackfriars Bridge (A201) in the east. It includes the junctions of:

[v] VISSIM is a traffic microsimulation software package widely used in the transport planning industry to model smaller areas of the highway network, including signal junctions, in greater detail using animated representations of the highway network operation to aid understanding of network operation together with the output of operational statistics.

a. Westminster Bridge (A302) / Bridge Street / Victoria Embankment (A3211)

b. Victoria Embankment (A3211) / Horse Guards Avenue

c. Victoria Embankment (A3211) / Northumberland Avenue

d. Victoria Embankment (A3211) / Savoy Place / Savoy Street

e. Victoria Embankment (A3211) / Temple Place (west)

f. Victoria Embankment (A3211) / Temple Place (east)

g. Victoria Embankment (A3211) / Temple Avenue

h. Victoria Embankment (A3211) eastbound slip road / New Bridge Street (A201) / Queen Victoria Street

i. Blackfriars Bridge (A201) / Victoria Embankment (A3211) westbound slip road

j. Queen Victoria Street / Puddle Dock

k. Upper Thames Street (A3211) / Puddle Dock.

VISSIM assessment time periods

12.3.50 The VISSIM model addresses the AM (07:00 to 10:00) and PM (16:00 to 19:00) peak periods and has been developed for the construction base and development cases. The assessment compares the construction base case and construction development case VISSIM model outputs.

12.3.51 The VISSIM model has considered three scenarios for the development case, which represent different traffic management requirements at the two sites. This assists in understanding whether and how different stages of construction might affect this part of the highway network. The three scenarios can be summarised as:

a. Scenario 1: utility diversion works at Victoria Embankment Foreshore, involving narrowing Victoria Embankment (A3211) whilst maintaining two lanes in each direction. This situation would occur in Project Year 1 and there would be no construction taking place at Blackfriars Bridge Foreshore at this time

b. Scenario 2: phases 1 and 2 of construction at Blackfriars Bridge Foreshore, involving reducing the width of the westbound slip road onto Victoria Embankment (A3211) but not complete closure. This would occur in Project Year 3 and also represents the time at which the number of construction vehicle movements from the Blackfriars Bridge Foreshore site would be greatest. Construction traffic from the Victoria Embankment Foreshore site has been included in the model

c. Scenario 3: phase 3 of construction at Blackfriars Bridge Foreshore, involving the closure of the westbound slip road onto Victoria Embankment (A3211). This would occur in Project Year 4.

VISSIM model traffic flows

12.3.52 In order to ensure that the VISSIM assessment provides a consistent basis for comparison between the three scenarios set out above, the same traffic flows have been used in each scenario. These represent baseline traffic flows, together with background traffic growth to form the base case. The development case includes the Thames Tideway Tunnel construction traffic flows that are the greatest that would be produced in total from the Victoria Embankment Foreshore and Blackfriars Bridge Foreshore sites, which would occur in Project Year 3.

VISSIM validation and calibration

12.3.53 The baseline VISSIM model for the AM and PM peak hours has been calibrated to represent conditions on the highway network, including they way in which traffic behaves at certain locations within the modelled network particularly when queuing occurs.

12.3.54 The VISSIM model has also been validated to ensure it provides a reasonable representation of existing conditions and a reasonable basis for comparison between the base and development cases.

Assumptions and limitations

12.3.55 The general assumptions and limitations associated with the assessment are presented in Vol 2 Section 12. There are no further assumptions or limitations specific to the assessment of project-wide effects.

12.4 Baseline conditions

12.4.1 The following section sets out the baseline conditions for the strategic public transport and highway networks within the assessment area. It also describes general baseline conditions in relation to river movements. Future baseline conditions (base case) are also described.

Current baseline

Public transport

12.4.2 London has one of the densest public transport networks of any city in the world. In 2010, some 34% of trips in Greater London were made by public transport (*Travel in London, Report 4* (TfL, 2011)[4]) and the share of public transport trips, as a proportion of the total number of journeys, has been increasing steadily since the early 1990s. Around 90% of all journeys into central London in the morning peak period are made by public transport modes.

12.4.3 The public transport network comprises buses, London Underground, the Docklands Light Railway (DLR) and London Overground services, all of which are managed by TfL either directly or through contracted service operators. In addition, National Rail services provide links to suburban locations and beyond. Regular river passenger services are provided by service operators under contract to TfL and the navigational governance of the PLA; other leisure passenger services on the river are provided by private operators. TfL also administer taxis (black cabs) and licenced private hire vehicles.

Public Transport Accessibility Level

12.4.4 TfL has developed a methodology for determining the Public Transport Accessibility Level (PTAL) of individual locations. This is based on the number of public transport services available within a 640m walking distance of the location (for bus services) or a 960m walking distance (for rail and river services) and produces a rating based on a scale of 1a (very low accessibility) to 6b (excellent accessibility).

12.4.5 A PTAL assessment has been undertaken within each of the site-specific assessments contained in Section 12 of Vols 4 to 27. As PTAL provides a measure of the availability of public transport at a particular location it is not directly relevant to the project-wide assessment but provides useful background information for the site-specific assessments.

Buses

12.4.6 London has a comprehensive bus network providing a range of daytime, night-time and 24 hour bus services. In 2010, approximately 3.7 million journeys on average were made on London’s buses every day (TfL,2011)[5] representing 15% of all journeys made in the Greater London area. The bus network carries around 2.3 billion passengers every year.

12.4.7 Buses operate 24 hours a day through a combination of daytime, Night Bus and 24-hour routes. The network is operated using a number of vehicle types with capacities ranging from approximately 40 to 90 passengers per vehicle.

12.4.8 All Thames Tideway Tunnel project construction sites are served by at least one bus route that passes within 640m walking distance[vi] of the site and sites in the central section of the project typically have access to a greater number of bus services with a range of destinations.

London Underground

12.4.9 The London Underground network has 11 lines covering some 400km of route and serving 270 stations. It carries over 1.1 billion journeys per year (TfL, 2011)[6] and together with the Docklands Light Railway carries approximately 2.1 million journeys on average every day or around 8% of all journeys made in the Greater London area.

12.4.10 London Underground trains typically have capacity in the order of 1,000 passengers per train.

12.4.11 At least one London Underground services is available within a 960m walking distance of seven of the 24 Thames Tideway Tunnel project construction sites and a further 11 sites have an Underground services within 1.6km or 20 minutes walk.

[vi] Distances derived from the Public Transport Accessibility Level (PTAL) methodology described in Vol 2 Section 12.

Docklands Light Railway

12.4.12 The DLR serves a network of stations in east and south-east London, extending between the City of London, Stratford, London Docklands and Greenwich. Trains vary in capacity between approximately 200 and 400 passengers per train, depending on train formation.

12.4.13 The DLR carries around 80 million passengers a year (Docklands Light Railway website, 2012)[7]. DLR services are available within 960m walking distance of five of the Thames Tideway Tunnel project construction sites.

London Overground

12.4.14 London Overground is operated by TfL and provides heavy rail services on an orbital network encompassing Croydon, Clapham Junction, Willesden Junction, Gospel Oak, Walthamstow, Highbury and Islington, Stratford, Barking, Whitechapel, New Cross and Crystal Palace. London Overground also operates over the route from Euston to Watford Junction.

12.4.15 Trains have typical capacities of approximately 400 to 500 passengers per train, depending on formation. The London Overground network carried around 54 million passenger journeys in 2010/11 (Travel in London, Report 4 (TfL, 2011)[8]).

12.4.16 London Overground services are available within a 960m walking distance of five Thames Tideway Tunnel project construction sites and are within 1.6km of a further three sites.

National Rail

12.4.17 National Rail services are provided by a number of train operators depending on the routes served. Services in central London operate from a number of key rail termini, including London Bridge, Cannon Street, Charing Cross, Waterloo, Paddington, Marylebone, Euston, St Pancras, Kings Cross, Liverpool Street and Fenchurch Street. These stations are also served by London Underground services which allow onward travel to other destinations.

12.4.18 In addition to routes serving these termini, National Rail routes pass through central London on the West London Line via Clapham Junction, Imperial Wharf and Willesden Junction and on the Thameslink route via London Bridge, Blackfriars, Farringdon and Kings Cross St Pancras.

12.4.19 Train formations vary by service and time of day and capacity ranges between 400 and 1,200 passengers per train.

12.4.20 National Rail services at termini or on routes serving them are available within 960m walking distance of 12 Thames Tideway Tunnel project construction sites and are within 1.6km of a further six sites.

Taxis

12.4.21 Taxis operated by the Public Carriage Office (part of TfL) also provide part of the public transport network around London. Licensed taxis are able to pick up and set down on demand at the kerbside and taxi ranks are provided throughout London, including at major stations.

12.4.22 Private hire vehicles are also licensed by TfL but are not permitted to pick up or set down at will. Pre-booking is necessary and specific ranking or parking facilities is not normally provided for these vehicles.

River services

12.4.23 River passenger services are discussed in paras. 12.4.24 to 12.4.31 below.

River movement

12.4.24 The River Thames is used by passenger services, freight operators, leisure users and marine emergency services.

12.4.25 Frequent river passenger services operate from 18 piers along the river. Regular services operate between Putney Pier in the west and Woolwich Arsenal Pier in the east, with an increased concentration of services downstream of Westminster Pier. These services typically offer several journeys per hour and operate in the morning and evening peak periods, depending on the locations served.

12.4.26 There are also a number of individual river tour operators offering services along the river. These operate to frequencies which are different to those for the regular river passenger services referred to in para. 12.4.25 and include a service between Westminster and Hampton Court Palace which operates upstream of Putney Pier.

12.4.27 Freight operators use the river for a variety of reasons which include the transport of waste to and from existing waste transfer stations with river access (at Smugglers Way, Cringle Dock, Walbrook Wharf and Northumberland Wharf). Aggregates are also transported by river to concrete batching plants at Kirtling Wharf, Pier Wharf and Comley's Wharf.

12.4.28 The river is also used by marine emergency services including the Police and the Royal National Lifeboat Institution (RNLI).

12.4.29 The site-specific assessments in Section 12 of Vols 4 to 27 include, where relevant, consideration of the number of vessel movements on the river in the context of assessing the transport effects of barge movements to and from certain Thames Tideway Tunnel project construction sites.

12.4.30 An analysis has been made of the typical volume of river vessel traffic passing each of the construction sites, based on published river passenger service timetables and estimates of freight traffic based on discussions with operators.

12.4.31 That analysis suggests that typically at upstream sites such as Putney Embankment Foreshore, a peak of around seven vessel movements per hour passing the site is experienced during the summer months when river activity tends to be at its greatest. This increases further downstream, to typical levels of 15 vessel movements per hour passing Chelsea Embankment Foreshore, 32 passing Victoria Embankment Foreshore and 35 passing Chambers Wharf.

Highway network

12.4.32 The road network in London is around 13,800km in total length and is managed by the Highways Agency, TfL and the London boroughs. In broad terms it is made up of:

a. motorways within the GLA boundary, which are managed by the Highways Agency

b. the TfL Road Network (TLRN), also known as the 'Red Route' network, for which TfL is the highway authority. This comprises strategic arterial and orbital routes carrying significant volumes of traffic and includes around 580km of London's road network

c. the wider Strategic Road Network (SRN) comprising a further 500km of roads considered to be strategic routes within the capital. These are maintained by the London boroughs, but TfL has a strategic responsibility to coordinate works and ensure the free flow of traffic on these routes, through the Traffic Management Act 2004[9]

d. the remainder of the network comprising a range of road types for which the London boroughs are the highway authorities.

12.4.33 For the highway network, the baseline situation at the project-wide level has been represented by the outputs from the modelled base year in the 2008 / 2009 TfL HAMs. These form the basis for the forecasting carried out within those models by TfL, during model preparation, in order to create a base case model for 2021.

12.4.34 A range of key statistics from the TfL HAMs for the baseline can be used for comparison with the construction base and development cases, to indicate how overall conditions on the highway network are expected to change from baseline to base case, without the Thames Tideway Tunnel project. Base case statistics are shown in Vol 3 Table 12.4.5 and Vol 3 Table 12.4.6. Development case statistics are shown in Vol 3 Table 12.5.6, Vol 3 Table 12.5.7 and Vol 3 Table 12.5.8.

12.4.35 These key statistics, which present the total or average results from the WeLHAM, CLoHAM and ELHAM models, are shown in Vol 3 Table 12.4.1.

Vol 3 Table 12.4.1 Transport – baseline highway network statistics

Model	Transient queues[a]	Over-capacity queues[b]	Total link cruise times[c]	Total travel time[d]	Total travel distance[e]	Average speed[f]
	Pcu[g]-hrs	pcu-hrs	Hours	pcu-hrs	pcu-km	km/h
AM peak hour						
WeLHAM	23,654	10,522	61,668	95,844	3,203,443	33.4
CLoHAM	12,429	1,595	17,196	31,220	554,211	17.8
ELHAM	21,075	7,652	57,088	85,815	2,777,070	32.4
PM peak hour						
WeLHAM	25,176	13,978	62,786	101,941	3,238,912	31.8

Model	Transient queues[a]	Over-capacity queues[b]	Total link cruise times[c]	Total travel time[d]	Total travel distance[e]	Average speed[f]
	Pcu[g]-hrs	pcu-hrs	Hours	pcu-hrs	pcu-km	km/h
CLoHAM	11,305	2,089	16,256	29,650	517,568	17.5
ELHAM	20,965	7,317	55,871	84,153	2,750,265	32.7

a) Transient queues – total time spent in 'under-capacity' queues (eg, queues which form at a red signal but dissipate during the following green period)
b) Over-capacity queues – total time spent in queues which form due to lack of capacity (eg, queues which form at a red signal but do not clear in the following green period)
c) Total link cruise time – total time spent travelling along links within the modelled network, excluding time spent queuing
d) Total travel time – sum of transient queue, over-capacity queue and link cruise times
e) Total travel distance – total distance travelled by all vehicles within the model network during the modelled period
f) Average speed – speed of vehicles averaged across the whole network and the whole modelled period (total travel distance / total travel time)
g) pcu – passenger car unit; a unit representing the equivalent of one car. Different vehicle types have different pcu values (eg, car = one pcu, vans and three-axle vehicles = 1.5 pcu, buses and coaches = two pcu, four-axle vehicles = 2.3 pcu).

12.4.36 Vol 3 Table 12.4.1 shows that the overall average speed of vehicles within the WeLHAM and ELHAM models is in excess of 30 km/h in both the AM and PM peak hours. Within the CLoHAM model covering the central London area, average speeds are lower at around 17 km/h but are again similar in both peak hours.

12.4.37 The baseline VISSIM models for the sub-area assessment for Victoria Embankment (A3211) have been prepared, calibrated and validated as described in paras. 12.3.43 to 12.3.54. Baseline results are presented together with base case results in paras. 12.4.65 to 12.4.68.

Transport receptors and sensitivity

12.4.38 Individual receptors have been identified as part of the site-specific assessments presented in Section 12 of Vols 4 to 27. For the project-wide assessment of construction transport effects, the relevant receptors are groups of transport users rather than specific individuals at specific locations.

12.4.39 The receptor categories and their sensitivities in terms of the strategic nature of this assessment are summarised in Vol 3 Table 12.4.2. Transport receptor sensitivity is defined as high, medium or low using the criteria detailed in Vol 2 Section 12.

12.4.40 It should be noted that the sensitivities identified in Vol 3 Table 12.4.2 are determined from consideration of the strategic nature of the project-wide assessment. Receptors within these groups at specific locations have been considered in the site-specific assessments in Section 12 of Vols 4 to 27.

Vol 3 Table 12.4.2 Transport – project-wide receptors and sensitivity

Receptors (relating to all identified transport effects)	Value/sensitivity and justification
Private vehicle users travelling on the highway network in west, central and east London	Low to medium sensitivity to changes in highway journey time and delay
Emergency vehicles travelling on the highway network in west, central and east London	High sensitivity to changes in highway journey time and delay
Bus passengers and operators of bus services on the network in west, central and east London	Low to medium sensitivity to changes in service patronage and changes in highway journey time and delay
Users of rail services on the network serving west, central and east London	Low sensitivity to changes in service patronage
Users of river passenger services on the River Thames	Low to medium sensitivity to changes in service patronage
Marine emergency services	High sensitivity to changes in barge movements
Leisure users of the River Thames	High sensitivity to changes in barge movements or river access points
River vessel operators	Medium sensitivity to changes in barge movements

Construction base case

Public transport

12.4.41 TfL undertakes a constant review of the bus network, patronage and operator performance as part of its overall management and operational role. Where necessary, changes to routes and services are addressed through contracts with bus operators. This means that bus route changes tend to be more responsive to circumstances and planned over a shorter time horizon than rail service changes. A similar pattern is seen in relation to river passenger services.

12.4.42 TfL has been undertaking a significant upgrade programme on the London Underground network in order to provide new trains, additional capacity, increased service frequency and reliability and improved station facilities. The overall programme is covered in the TfL London Underground Upgrade Plan (TfL, 2011)[10]. A significant proportion of the planned upgrade work has already been completed and is therefore reflected in the baseline conditions for this assessment. Further capacity enhancements have still to be completed at the time of writing this assessment.

12.4.43 Work to extend the London Overground network has now been completed, with services on the final link between Clapham Junction and Surrey

Quays having commenced in December 2012. It is not expected that further capacity or service upgrades will take place in the immediate future.

12.4.44 Changes to National Rail services may occur as a result of enhancement proposals by train operating companies, whether as part of ongoing projects, in response to specific issues that may arise, or as part of refranchising negotiations that will take place from time to time.

12.4.45 The Thameslink programme involves a significant upgrade of the route between Brighton and Bedford, including improved infrastructure and signalling and longer trains. Improvements to Blackfriars and Farringdon stations were completed in 2012 and a major upgrade of London Bridge station is due to commence in 2013. The whole programme is scheduled for completion in 2018.

12.4.46 Crossrail will provide a new east-west rail link across London and is expected to be operational in 2018. The central section will be in tunnel and will link to existing stations at Paddington, Bond Street, Tottenham Court Road, Farringdon and Liverpool Street. The entire route will connect Maidenhead and Slough in the west to Stratford, Shenfield, Canary Wharf and Abbey Wood in the east.

12.4.47 There are no advanced plans for further enhancements to DLR services with a number of capacity enhancements having taken place in advance of the London 2012 Olympic and Paralympic Games including the extension of the network between Canning Town and Stratford International and work to accommodate three-car trains across the network.

12.4.48 Overall, therefore, it can be expected that some change to the public transport networks will take place between the baseline and the base case (Project Year 2 of construction for the western cluster peak of construction activity, and Project Year 4 of construction for project-wide construction activity). Furthermore, it is reasonable to expect that such changes would deliver increased overall capacity and service coverage on each of the public transport networks, in response to changing demand.

12.4.49 In addition, it is expected that patronage on public transport services will change over time. These changes will be driven by a range of complex factors and there are inherent uncertainties involved in setting a specific patronage level for public transport for a future year.

12.4.50 Given the range of changes that might occur, and the general trend towards providing increased capacity on the network to accommodate increased patronage, the assessment assumes that public transport capacity in the construction base case is the same as that in the current baseline situation. This means that the assessment takes no advantage of any additional capacity that might become available in future years and is therefore considered robust.

River movements

12.4.51 The underlying pattern of river usage has not substantially changed in recent years, but the Mayor of London and TfL do actively promote the use of passenger services and encourage the provision of more piers (for example the new St George Wharf Pier at Nine Elms). For example, it is anticipated that river passenger services between Putney and Blackfriars may increase from baseline conditions as a result of planned services which were being tendered at the time of writing. Greater freight use is also encouraged and both passenger and freight use are promoted through policies in the London Plan (GLA, 2011)[11]. The nature and number of vessel movements on the River Thames may change over time and may therefore not be the same in the construction base case as in the baseline.

12.4.52 However, it is difficult to determine what the scale and nature of any change might be, as it may be related to river passenger service changes or to changes in river freight operations.

12.4.53 For the purposes of this assessment, the construction base case for assessing the effects on river movements has been assumed to be the same as the baseline situation.

Highway network

12.4.54 The highway network across London is not expected to undergo significant change at a strategic level, as it already provides a dense network serving a range of purposes. Local changes to improve capacity and network efficiency, address safety or provide access to new development are likely to take place in many locations between the baseline and base case situation.

12.4.55 The construction base case for the highway network assessment has been taken as being represented by the TfL HAMs for the 2021 forecast year. As explained in Vol 2 Section 12, this has been agreed with TfL and provides consistency between this assessment and the work already undertaken by TfL.

12.4.56 The construction base case does not include any traffic related to the Thames Tideway Tunnel project sites.

Highway schemes and network alterations

12.4.57 The 2021 HAMs contain changes made to the baseline network by TfL in order to incorporate known highway schemes and infrastructure proposals. These are summarised in Vol 3 Table 12.4.3 below.

Vol 3 Table 12.4.3 Transport – highway schemes within TfL HAMs

Model	Highway schemes included in 2021 model
WeLHAM	Cycle Superhighway Scheme (CS9) Hounslow to Hyde Park A4 M25 Widening Removal of Western Extension Zone
CLoHAM	Heron Tower Route 38 Bloomsbury Way Route 38 Piccadilly Circus Aldgate Gyratory

Model	Highway schemes included in 2021 model
	Marble Arch Pedestrian Crossings London Bridge Thameslink Exhibition Road Elephant & Castle Gyratory Removal of Western Extension Zone M25 Widening and Hard Shoulder Running
ELHAM	Kender Street and Besson Street A2 / A202 Removal of Western Extension Zone Canning Town Roundabout change to signals Sydenham Road Area Based Scheme A212 M25 Widening and Hard Shoulder Running **London 2012 Olympic Games and legacy schemes** White Post Lane / Waterden Road / Carpenters Road Lea Interchange / Waterden Road E28 Link and LO3 Safeguarding Highway in the vicinity of Aquatics / Stratford City Southern Access Road Marshgate Lane / Southern Loop Road Park Street / Velodrome Link North Loop Road / Temple Mill Lane Ruckholt Road Highway Link Assessment **Olympic Park Transport and Environmental Management Schemes (OPTEMS)** Cadogan Terrace Traffic Calming Eastway Improvements Balls Pond Road / Southgate Road North-South Residential Traffic Priorities – Implementation Cadogan Terrace and 'Missing Link' Enhancements Ruckholt Road Area

Development proposals

12.4.58 In addition to physical changes to the highway network, the TfL HAMs are based on forecasts for change in employment and housing within London over the period to 2021. These are built up from the London Travel Survey (LTS) model, which is a strategic model representing travel patterns in London.

12.4.59 The LTS model contains over 1,000 zones and allows origin – destination matrices to be developed to represent future travel demand patterns, based on employment and population forecasts including those used by the GLA, which are in turn derived from those set out in the London Plan (GLA, 2011)[12].

Traffic growth

12.4.60 The outputs of the HAMs for the 2008 / 2009 and 2021 model years have been compared in order to provide an indication of growth in vehicle kilometres during the peak hours in the same period. This has been identified for each local authority area, as shown in Vol 3 Table 12.4.4, and these growth factors have been used in the highway modelling for the site-specific assessments to create base case traffic flows from the baseline traffic surveys.

Vol 3 Table 12.4.4 Transport – growth in vehicle kilometres

London borough	AM peak hour			PM peak hour		
	WeLHAM	CLoHAM	ELHAM	WeLHAM	CLoHAM	ELHAM
City of London		9%	4%	a	4%	.1%
LB Ealing	3.2%	0.3%	n/a	3.9%	4.5%	n/a
RB Greenwich	n/a	3.1%	6.8%	N/A	2.3%	4.5%
LB Hammersmith and Fulham	5.8%	6.5%	n/a	5.4%	7.4%	n/a
LB Hounslow	3.7%	4.0%	n/a	3.2%	6.5%	n/a
RB Kensington and Chelsea	10.7%	9.9%	n/a	14.9%	16.4%	n/a
LB Lambeth	1.8%	9.1%	n/a	3.0%	11.2%	n/a
LB Lewisham	n/a	n/a	2.6%	n/a	n/a	3.1%
LB Newham	n/a	n/a	11.7%	n/a	n/a	12.6%
LB Richmond upon Thames	1.5%	-0.6%	n/a	-1.5%	-0.2%	n/a
LB Southwark	n/a	13.6%	3.8%	n/a	12.3%	4.4%
LB Tower Hamlets	n/a	7.5%	11.1%	n/a	9.7%	11.2%
LB Wandsworth	3.6%	4.0%	n/a	4.6%	5.3%	n/a
City of Westminster	7.4%	4.7%	n/a	6.0%	6.1%	n/a

Note: Table shows % change in total veh km from 2008/9 to 2021 modelled years. Where n/a is shown, the authority area is not within the simulation area of the particular HAM.

Strategic highway network operation

12.4.61 The key model statistics from the 2021 HAMs, representing the construction base case, are shown in Vol 3 Table 12.4.5 and Vol 3 Table 12.4.6. Baseline key model statistics are also provided for comparison purposes.

Vol 3 Table 12.4.5 Transport – base case highway network statistics, AM peak hour

Model	Transient queues[a]	Over-capacity queues[b]	Link cruise times[c]	Total travel time[d]	Travel distance[e]	Average speed[f]
	pcu[g]-hrs	pcu-hrs	hours	pcu-hrs	pcu-km	km/h
WeLHAM						
Baseline	23,653	10,522	61,668	95,844	3,203,443	33.4
Base case	26,253	13,458	66,155	105,867	3,454,429	32.6
Change	11.0%	27.9%	7.3%	10.5%	7.8%	-2.4%
CLoHAM						
Baseline	12,429	1,595	17,196	31,220	554,211	17.8
Base case	13,637	3,193	20,249	37,078	666,664	18.0
Change	9.7%	100.1%	17.8%	18.8%	20.3%	1.1%
ELHAM						
Baseline	21,075	7,652	57,088	85,815	2,777,070	32.4
Base case	23,663	9,099	62,277	95,039	3,089,251	32.5
Change	12.3%	18.9%	9.1%	10.7%	11.2%	0.3%

a) Transient queues – total time spent in 'under-capacity' queues (eg, queues which form at a red signal but dissipate during the following green period)
b) Over-capacity queues – total time spent in queues which form due to lack of capacity (eg, queues which form at a red signal but do not clear in the following green period)
c) Total link cruise time – total time spent travelling along links within the modelled network, excluding time spent queuing
d) Total travel time – sum of transient queue, over-capacity queue and link cruise times
e) Total travel distance – total distance travelled by all vehicles within the model network during the modelled period
f) Average speed – speed of vehicles averaged across the whole network and the whole modelled period (total travel distance / total travel time)
g) pcu – passenger car unit; a unit representing the equivalent of one car. Different vehicle types have different pcu values (eg, car = one pcu, vans and three-axle vehicles = 1.5 pcu, buses and coaches = two pcu, four-axle vehicles = 2.3 pcu)

Vol 3 Table 12.4.6 Transport – base case highway network statistics, PM peak hour

Model	Transient queues[a]	Over-capacity queues[b]	Link cruise times[c]	Total travel time[d]	Travel distance[e]	Average speed[f]
	pcu[g]-hrs	pcu-hrs	hours	pcu-hrs	pcu-km	km/h
WeLHAM						
Baseline	25,176	13,978	62,786	101,941	3,238,912	31.8
Base case	27,671	18,063	67,501	113,235	3,508,154	31.0
Change	9.9%	29.2%	7.5%	11.1%	8.3%	-2.5%
CLoHAM						
Baseline	11,305	2,089	16,256	29,650	517,568	17.5
Base case	12,786	3,713	19,602	36,101	639,045	17.7
Change	13.1%	77.7%	20.6%	21.8%	23.5%	1.1%
ELHAM						
Baseline	20,965	7,317	55,871	84,153	2,750,265	32.7
Base case	24,192	10,997	61,588	96,778	3,067,299	31.7
Change	15.4%	50.3%	10.2%	15.0%	11.5%	-3.1%

a) Transient queues – total time spent in 'under-capacity' queues (eg, queues which form at a red signal but dissipate during the following green period)
b) Over-capacity queues – total time spent in queues which form due to lack of capacity (eg, queues which form at a red signal but do not clear in the following green period)
c) Total link cruise time – total time spent travelling along links within the modelled network, excluding time spent queuing
d) Total travel time – sum of transient queue, over-capacity queue and link cruise times
e) Total travel distance – total distance travelled by all vehicles within the model network during the modelled period
f) Average speed – speed of vehicles averaged across the whole network and the whole modelled period (total travel distance / total travel time)
g) pcu – passenger car unit; a unit representing the equivalent of one car. Different vehicle types have different pcu values (eg, car = one pcu, vans and three-axle vehicles = 1.5 pcu, buses and coaches = two pcu, four-axle vehicles = 2.3 pcu).

12.4.62 Vol 3 Table 12.4.5 and Vol 3 Table 12.4.6 show that comparing the construction base case (without the Thames Tideway Tunnel project), to the baseline in the AM peak hour, total travel time within the modelled networks would increase by around 10% in west and east London and by 19% in central London. Average speeds would reduce slightly in west London, increase slightly in central London and remain similar in east London.

12.4.63 In the PM peak hour, total travel time would increase by a similar order of magnitude to that in the AM peak hour. The pattern for average speeds shows reductions in west and east London, with a slight increase in central London.

12.4.64 It should be noted that the HAMs, as highway network models, take no iterative account of the potential for increased uptake of alternative transport modes such as public transport, as capacity on those modes increases over time, and if that were to occur the change in vehicle speeds and journey times could potentially be smaller than indicated in the base case HAMs statistics.

Sub-area (VISSIM) network operation

12.4.65 The construction base case VISSIM models for the AM and PM peak hours provide an indication of how journey times along Victoria Embankment (A3211) and related routes might change between the baseline and base case, as a result of changes to traffic flows and the operation of signal junctions. Further details of signal junction operation are provided in Section 12 of the relevant site volumes of the *Environmental Statement* (see Vols 17 and 18).

12.4.66 To compare the baseline and base case operation of the Victoria Embankment (A3211) VISSIM network, journey times have been identified for 12 possible routes through the network that has been modelled. Vol 3 Table 12.4.7 and Vol 3 Table 12.4.8 show the baseline and base case journey time results for the AM and PM peak hours respectively.

Vol 3 Table 12.4.7 Transport – VISSIM base case journey times, AM peak hour

Route		Direction	Modelled journey time (mm:ss)		
			Baseline	Base case	Change
Bridge Street (A302) to Upper Thames Street (A3211)	1	Eastbound	05:18	05:29	+00:11
	2	Westbound	05:50	06:20	+00:30
Blackfriars Bridge (A201) to New Bridge Street (A201)	3	Northbound	01:57	01:42	-00:15
	4	Southbound	01:00	01:21	+00:21
Northumberland Avenue to Upper Thames Street (A3211)	5	Eastbound	04:04	04:16	+00:12
	6	Westbound	04:26	04:32	+00:06
Northumberland Avenue to New Bridge Street (A201)	7	Eastbound	04:49	04:44	-00:05
	8	Westbound	05:13	05:39	+00:26
Westminster Bridge (A302) to New Bridge Street (A201)	9	Eastbound	06:32	06:37	+00:05
	10	Westbound	05:58	06:31	+00:33
Upper Thames Street (A3211) to Westminster Bridge (A302)	11	Westbound	05:48	06:20	+00:32
	12	Eastbound	05:59	06:05	+00:06

Vol 3 Table 12.4.8 Transport – VISSIM base case journey times, PM peak hour

Route		Direction	Modelled journey time (mm:ss)		
			Baseline	Base case	Change
Bridge Street (A302) to Upper Thames Street (A3211)	1	Eastbound	05:57	05:55	-00:02
	2	Westbound	05:54	06:56	+01:02
Blackfriars Bridge (A201) to New Bridge Street (A201)	3	Northbound	01:16	01:19	+00:03
	4	Southbound	01:01	01:05	+00:04
Northumberland Avenue to Upper Thames Street (A3211)	5	Eastbound	04:05	04:22	+00:17
	6	Westbound	05:07	05:10	+00:03
Northumberland Avenue to New Bridge Street (A201)	7	Eastbound	04:37	05:00	+00:23
	8	Westbound	06:04	06:21	+00:17
Westminster Bridge (A302) to New Bridge Street (A201)	9	Eastbound	07:04	07:05	+00:01
	10	Westbound	06:15	07:27	+01:12
Upper Thames Street (A3211) to Westminster Bridge (A302)	11	Westbound	06:30	08:07	+01:37
	12	Eastbound	06:28	06:39	+00:09

12.4.67 Vol 3 Table 12.4.7 shows that in the AM peak hour, journey times would increase in the base case compared to the baseline situation on most routes through the VISSIM model network. The changes tend to be greater in the westbound direction along Victoria Embankment (A3211), where increases of up to some 30 seconds are shown.

12.4.68 Vol 3 Table 12.4.8 shows a similar pattern for the PM peak hour with increases to journey times on most routes. The increases would again be greatest in the westbound direction, with those on the routes passing the full length of Victoria Embankment (A3211) experiencing increases of between 60 and 90 seconds.

Transport receptors and sensitivity

12.4.69 In the base case, there are no additional receptors to be considered beyond those set out in Vol 3 Table 12.4.2.

12.5 Construction effects assessment

12.5.1 This section summarises the findings of the assessment undertaken for the project-wide peak periods of construction activity. These are Project Year 2 of construction (western cluster peak) and Project Year 4 of construction (project-wide peak and central and eastern cluster peaks) for the public transport and highway network assessments and Project Year 2 of construction for the river movement assessment.

Worker mode split and overall trip generation

12.5.2 As the resident addresses of workers at project sites are not yet known, the anticipated mode split of worker trips has been generated for each site individually, based on 2001 Census data for journeys to workplaces within the vicinity of each site[vii]. The site-specific mode shares are detailed in Section 12 of Vols 4 to 27.

12.5.3 The 2001 Census data has been adjusted on a pro-rata basis where necessary to take account of the fact that at the majority of construction sites, there would be no parking for construction workers within the site boundary. Site-specific *Travel plan* requirements would include measures to reduce car use and in many locations, on-street parking in the surrounding area is already restricted. At most sites, therefore, it is highly unlikely that any workers would travel by car and opportunities for workers to access sites by public transport are good.

12.5.4 The emphasis on minimising the number of workers travelling by car would apply across the project. However, the site-specific assessments recognise that at a few sites, parking in surrounding streets is not restricted and for those sites, the assessment considers the effects if a proportion of workers were to drive to the site, in order to ensure that the assessment is robust.

12.5.5 Vol 3 Table 12.5.1 below combines the mode split assumptions made at each of the 24 construction sites to present the overall mode split for worker journeys across the project.

Vol 3 Table 12.5.1 Transport – overall worker mode split

Mode	AM peak period (07:00 – 09:00)		PM peak period (17:00-19:00)	
	Percentage of trips to sites	Approximate number of trips (arrivals and departures)	Percentage of trips to sites	Approximate number of trips (arrivals and departures)
Bus	16.9%	333	16.0%	239
National Rail / London Overground	25.5%	501	25.3%	376
Underground	20.6%	406	20.9%	313
DLR	3.4%	66	3.3%	49
Car driver	12.6%	249	14.0%	209
Car passenger	0.8%	15	0.9%	13

[vii] At the time of this assessment, this type of data had not yet been released from the 2011 Census.

Mode	AM peak period (07:00 – 09:00)		PM peak period (17:00-19:00)	
	Percentage of trips to sites	Approximate number of trips (arrivals and departures)	Percentage of trips to sites	Approximate number of trips (arrivals and departures)
Cycle	4.1%	81	4.0%	60
Walk	11.9%	235	11.5%	172
River	0.7%	13	0.6%	10
Other (taxi / motorcycle)	3.7%	73	3.5%	52
TOTAL	100%	1972	100%	1,493

Notes: Mode splits for the AM and PM peak periods will differ slightly because some shift workers will arrive or depart outside the peak periods.
Workers have been assumed to travel by car to a small number of construction sites to ensure a robust assessment. In practice site-specific Travel plans and the provision of no parking for workers on sites means that it is unlikely this number of workers would travel by car.
Number of trips is shown for two-hour peak periods, which includes the busiest arrival and busiest departure hours in each case.

12.5.6 Vol 3 Table 12.5.1 shows that the predominant form of travel for workers is expected to be public transport, with just fewer than 70% of workers using bus, rail or river services to travel to and from construction sites.

12.5.7 The table also indicates that between 11% and 12% of workers might drive to construction sites. As noted in para 12.5.4, this arises from a small number of construction sites for which the assessment assumes workers might drive, in order to be robust. In practice, site-specific *Travel plan* measures would be in place with the objective of minimising car use by workers.

12.5.8 The table also indicates that the proportion of workers travelling as car passengers, based on the 2001 Census information, would be low. However, in support of measures to reduce car use, the site-specific *Travel plans* would also include measures to increase car sharing if workers have to travel by car.

Public transport network

Bus network

12.5.9 Vol 3 Table 12.5.1 indicates that in the AM two-hour peak period, approximately 330 journeys would be made by bus by workers travelling to or from Thames Tideway Tunnel project construction sites. In the PM two-hour peak period there would be approximately 240 additional bus journeys. These journeys would be spread across the bus network serving the 24 construction sites.

12.5.10 The site-specific assessments show that the number of bus journeys in the AM peak hour to and from all project sites would be approximately 270 with a corresponding figure of about 220 in the PM peak hour. At individual sites the number of bus journeys would be less than 15 at all but the four main tunnel sites, from which between 20 and 50 journeys would be expected in the AM peak hour and up to 30 journeys in the PM peak hour.

12.5.11 The criteria for determining impact on public transport patronage are set out in Vol 2 Section 12 and are described as the change in journey numbers relative to the capacity of the relevant services.

12.5.12 The site-specific assessments conclude that in all cases, the impact on bus patronage from additional worker journeys made by bus would be negligible. To place the overall number of additional journeys in context, the 270 and 220 journeys expected in the AM and PM peak hours respectively would be equivalent to the capacity of approximately six and five buses respectively (based on an average capacity of 50 passengers per bus), spread across the London bus network.

12.5.13 On that basis and given the comprehensive nature of the bus network in London, the project-wide impact on bus patronage has also been assessed as negligible.

12.5.14 It is also relevant to consider the impact on bus journey times as a consequence of the additional construction traffic movements on the highway network. The outcomes of the highway network assessment at the project-wide level are reported in paras. 12.5.48 to 12.5.77 and conclude that the impact on road network delay at the project-wide level would be negligible.

12.5.15 The outcomes of the sub-area assessment for Victoria Embankment (A3211) are reported in paras. 12.5.93 to12.5.107. In terms of road network delay, the sub-area assessment concludes that the impact in the Victoria Embankment (A3211) corridor would be negligible.

London Underground

12.5.16 Vol 3 Table 12.5.1 shows that there would be approximately 410 additional journeys made on the London Underground system in the AM two-hour peak period and 310 in the PM two-hour peak period. These journeys would be distributed across the Underground network.

12.5.17 The site-specific assessments indicate that the number of Underground journeys to and from all project sites in the AM peak hour would be approximately 350 with a corresponding figure of approximately 300 in the PM peak hour. The greatest number of Underground journeys to and from any one site would be approximately 70 journeys in the AM peak hour (both arrivals and departures from sites with shift working) and 40 journeys in the PM peak hour (all departing from sites), at sites where Underground services are available.

12.5.18 The site-specific assessments conclude that in all cases, the impact on London Underground patronage would be negligible. The total number of Underground journeys in Vol 3 Table 12.5.1 would be equivalent to approximately 30% to 35% of the typical capacity of a London Underground train, based on a capacity of 1,000 passengers per train.

12.5.19 On that basis and given that Underground journeys associated with the project would be spread across a number of London Underground lines and route directions, the project-wide impact on London Underground patronage has been assessed as negligible.

Docklands Light Railway

12.5.20 The number of additional journeys on DLR services would amount to around 65 journeys in the AM two-hour peak period and 50 in the PM two-hour peak period. In the busiest AM and PM peak hours, there would be approximately 50 and 45 DLR journeys respectively associated with all Thames Tideway Tunnel project sites. These journeys would be associated with sites in the eastern section of the project (King Edward Memorial Park Foreshore, Bekesbourne Street, Deptford Church Street, Greenwich Pumping Station, Abbey Mills Pumping Station and Beckton Sewage Treatment Works). The greatest number of additional journeys would arise from the Greenwich Pumping Station site.

12.5.21 The site-specific assessments for these sites conclude that in all cases, the impact on DLR patronage would be negligible.

12.5.22 The total number of journeys in the busiest peak hours would be the equivalent of 15% to 20% of the typical capacity of a DLR service (based on 300 passengers per DLR train) and when the journeys are distributed across the DLR network, the project-wide impact on DLR patronage would be negligible.

London Overground and National Rail

12.5.23 Vol 3 Table 12.5.1 shows that there would be approximately 500 additional journeys made on National Rail and London Overground services in the AM two-hour peak period and 380 additional journeys in the PM two-hour peak period.

12.5.24 The number of rail journeys using these services in the busiest AM and PM peak hours to and from all project sites would be approximately 420 and 350 respectively. The number of rail journeys generated from individual sites would vary from four to 80 journeys in the AM peak hour (both arrivals and departures from sites with shift working), although all but two of the sites would generate less than 40 rail journeys. In the PM peak hour there would be up to 50 journeys in the PM peak hour (all departing from sites).

12.5.25 National Rail services are available within 960m of 12 of the project sites and are within 1.6km (20 minutes walk) of a further six project sites. In some cases workers may choose to complete their journeys from National Rail stations by other transport modes including walking and using bus services.

12.5.26 London Overground services are available within 960m walking distance of five sites (Acton Storm Tanks, Falconbrook Pumping Station, Cremorne Wharf Depot, King Edward Memorial Park Foreshore and Earl Pumping

Station) and are within 1.6km (20 minutes walk) of the sites at Carnwath Road Riverside, Bekesbourne Street and Abbey Mills Pumping Station.

12.5.27 Journeys by National Rail and London Overground would therefore be distributed across a number of routes and stations. The overall number of additional trips in the busiest peak hours would be equivalent to between 60% and 70% of the capacity of a typical train (based on 600 passengers per train, adopted in this assessment to allow for variation in train formations).

12.5.28 The site-specific assessments conclude that in all cases, the impact on National Rail and London Overground patronage would be negligible. Given the range of rail routes available both into central London termini and in the vicinity of Thames Tideway Tunnel project construction sites, the project-wide impact on National Rail and London Overground patronage would also be negligible.

River passenger services

12.5.29 Vol 3 Table 12.5.1 shows that there would be approximately ten additional journeys made by construction workers on river services across the whole of the project during the AM and PM peak periods.

12.5.30 Bearing in mind the number of services available and the low level of additional journeys anticipated, this would result in a negligible impact on river passenger service patronage.

River movement

12.5.31 The project-wide effects of using the river to transport construction materials relate to the number of additional barge movements that would be introduced to the River Thames over the construction programme. This would fluctuate during construction as the number of movements would depend upon the phasing of the overall construction programme, nature of the materials being transported and the requirement for materials at individual sites at any particular time.

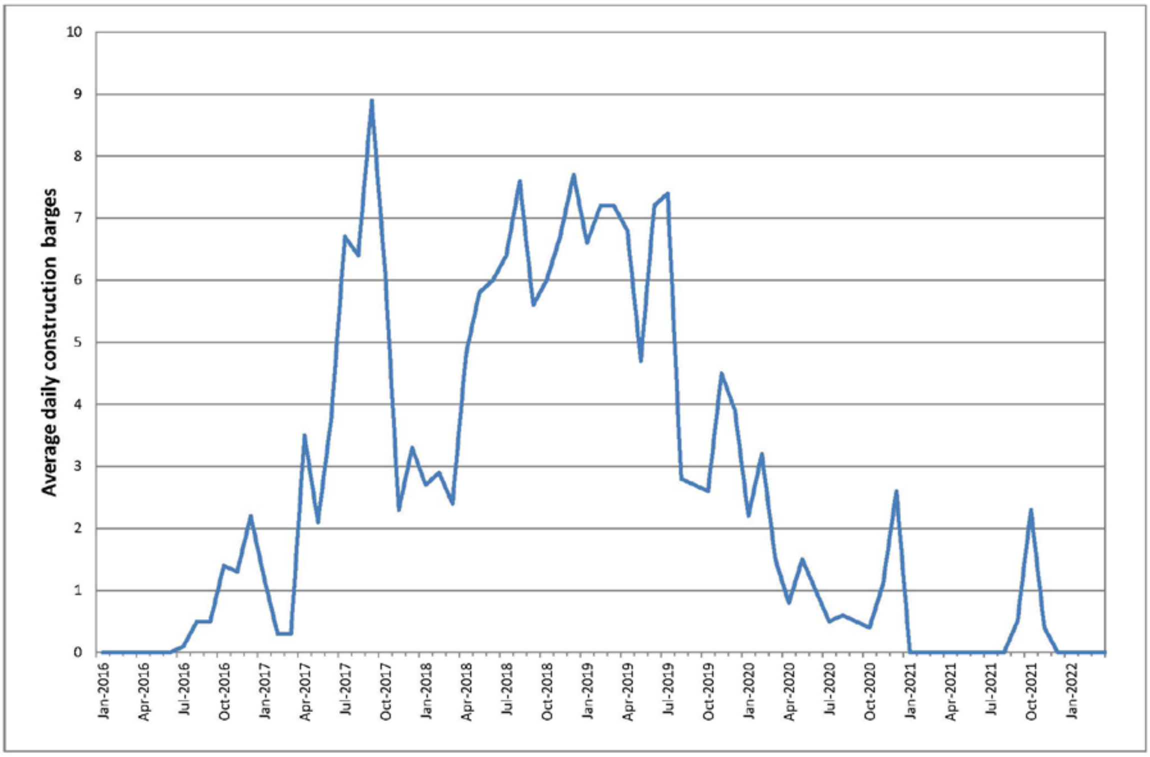
12.5.32 General navigational and river access issues presented by the movement of barges to and from loading / unloading points at the construction sites are discussed in general in Section 12 of Vols 4 to 27.

12.5.33 Additionally, separate navigational issues and preliminary risk assessments have been undertaken for all Thames Tideway Tunnel project sites where there would be in-river construction or it is proposed to use barges (see separate *Navigational Issues and Preliminary Risk Assessments report* which accompanies the application). The assessments consider safety hazards during construction and for the permanent works.

Construction barge movements

12.5.34 The *Transport Strategy* envisages using the river to transport materials at 11 of the sites. Vol 3 Plate 12.5.1 shows the combined profile of barge movements over the project programme.

Vol 3 Plate 12.5.1 Transport – average daily construction barge requirements, project-wide



12.5.35 Vol 3 Plate 12.5.1 shows that the project-wide peak month in which the total daily barge requirement would be greatest from all sites would be greatest would occur in Project Year 2 of construction. Vol 3 Table 12.5.2 shows the total number of barge deliveries and collections expected at these sites in the project-wide peak month in that year. The total number of barge and river transit movements over the whole project is shown in Vol 3 Table 12.2.2.

Vol 3 Table 12.5.2 Transport – barge movements, project-wide peak month

Site	Average daily river movements in project-wide peak month (Project Year 2)			
	Barges required	**Total barges delivered / collected**	**Total daily river transit movements**	**Typical barge size**
Putney Embankment Foreshore	0	0	0	350T
Carnwath Road Riverside	0	0	0	800T
Cremorne Wharf Depot	0	0	0	350T
Chelsea Embankment Foreshore	2	4	4	800T
Kirtling Street	0	0	0	1000T
Heathwall Pumping Station	1	2	2	350T
Albert Embankment Foreshore	3	6	4	350T
Victoria Embankment Foreshore	2	4	4	800T
Blackfriars Bridge Foreshore	1	4	4	800T
Chambers Wharf	0	0	0	1500T
King Edward Memorial Park Foreshore	0	0	0	1000T
Total	9	18	16	

Note: number of barge deliveries and collections has been rounded up in the table above; ie, the table assumes that barge movement would take place on the same day at all sites (where relevant) even where less than one barge per day would be required on average. Barge delivery and collection numbers show the number of barges required to arrive and depart at sites. The number of river transit movements would be influenced by the capacity of barges used at each site. Where smaller 350T barges are used, it is possible for a tug to haul two together. This might also be the case for 800T barges, depending on mooring conditions. However, for 1,000T and 1,500T barges it is unlikely that two would be hauled together. For this table it has been assumed that only 350T barges could be hauled together.

12.5.36 It can be seen from Vol 3 Table 12.5.2 that in the project-wide peak month for barge activity, there would be no barge requirements at the main tunnel sites at Carnwath Road Riverside, Kirtling Street or Chambers Wharf. This is because these sites would not require or be producing large quantities of materials at this point in the programme.

12.5.37 It is useful to note that the maximum number of barges required at Carnwath Road Riverside would be two per day, at Kirtling Street would be four per day and at Chambers Wharf would be three per day. However, this level of barge activity is not expected to occur at these sites until later in the construction programme (Project Year 3 at Carnwath Road Riverside and Kirtling Street and Project Year 6 at Chambers Wharf), when the total number of barges required at all Thames Tideway Tunnel project sites would be lower than in the peak month in Project Year 2.

12.5.38 As the footnote to Vol 3 Table 12.5.2 suggests, barges would be hauled by tugs and depending on barge size, two barges may be hauled together as part of a single river transit movement. Bearing in mind the range of barge sizes expected at different sites, as indicated in Vol 3 Table 12.2.4, it is estimated that there would be in the order of 16 river transit movements per day in total, if two barges are hauled together where it is possible to do so.

12.5.39 The transit of barges on the River Thames tends to coincide with the ebb and flow of tides in order to improve speed of passage and reduce the fuel consumption of tugs. As a result there would be periods of higher and lower transit activity on a daily basis, broadly related to tidal patterns.

12.5.40 The criteria for determining the magnitude of impact on river navigation are set out in Vol 2 Section 12. These have been used to assess the impact of barge movements at relevant sites in the site-specific assessments in Section 12 of Vols 4 to 27.

12.5.41 Using those criteria, in the project-wide peak month there would be 18 barge movements (nine deliveries and nine collections) per day, which would suggest a high adverse impact on river navigation if this total is assessed against the impact criteria as presented in Vol 2 Section 12. However, if the number of river transit movements is considered (16 from Vol 3 Table 12.5.2), this suggests that the impact would be classified as medium adverse.

12.5.42 However, in considering the project-wide effects associated with barge movements, it is also relevant to consider how the number of movements might vary along the length of the River Thames.

12.5.43 The number of barges required and associated river transit movements would reduce the further upstream a site is located. Vol 3 Table 12.5.2 shows that upstream of Chelsea Embankment Foreshore there would be no barge requirements on the river in the peak month of barge activity in Project Year 2; whereas downstream of King Edward Memorial Park Foreshore, up to 18 barge movements could be expected (or approximately 16 river transit movements).

12.5.44 The impact magnitude would therefore vary along the length of the river. On this basis the impact in relation to the movement of barges on the river for the project-wide peak month has been assessed to be as follows:

a. negligible upstream of Heathwall Pumping Station

b. low adverse between Heathwall Pumping Station and Albert Embankment Foreshore

c. medium adverse downstream of Albert Embankment Foreshore.

12.5.45 At other times in the construction programme there would be barge activity associated with the sites at Carnwath Road Riverside and Kirtling Street. As para. 12.5.37 explains, these sites would require two and four barge deliveries and the same number of collections (four and eight barge movements in total) respectively. This means that the number of river transit movements upstream of Heathwall Pumping Station would be greater, although activity at other sites would be lower and thus the overall total number of river transit movements would be lower than in the project-wide peak month.

12.5.46 When barges are in operation at Carnwath Road Riverside and Kirtling Street those two sites would contribute the majority of Thames Tideway Tunnel barge activity on this part of the river and would do so for a number of months in succession. At such times the impact magnitudes would differ slightly from those identified for the project-wide peak month in para. 12.5.44. In such situations the impact magnitudes based on the criteria in Vol 2 Section 12 would typically be:

a. negligible upstream of Kirtling Street

b. medium adverse downstream of Kirtling Street.

12.5.47 It is therefore considered appropriate to reflect this in the assessment of effects related to barge movements. Taking account of the impact magnitudes listed in paras. 12.5.44 and 12.5.46 and of the durations over which they apply, the overall effects have been assessed as:

a. negligible upstream of Carnwath Road Riverside

b. minor adverse between Carnwath Road Riverside and Kirtling Street

c. moderate adverse downstream of Kirtling Street.

Highway network

Approach to strategic modelling

12.5.48 The strategic highway modelling work has been used to assess the effects on the highway network in relation to changes in delay and journey time that would arise across the network as a whole as a result of the Thames Tideway Tunnel project.

12.5.49 A construction development case has been created in WeLHAM, CLoHAM and ELHAM which adds the forecast vehicle movements associated with the project in the peak activity months to the base case model flows.

Strategic modelling construction traffic scenarios

12.5.50 As paras. 12.3.33 to 12.3.42 explain the highway network modelling has examined four assessment scenarios. These are:

a. one scenario representing ‘project-wide’ peak of activity, which would occur in Project Year 4 of construction, and would be the month in which the aggregate average daily construction lorry movements for the project would be highest. This scenario has been tested in the WeLHAM, CLoHAM and ELHAM models

b. one scenario representing the month in which the aggregate average daily construction lorry movements would be highest for the sites in the WeLHAM model area. This would occur in Project Year 2 of construction and has been tested in the WeLHAM model, to which have been applied the aggregate average daily construction lorry movements from all sites in that month

c. one scenario representing the month in which the aggregate average daily construction lorry movements would be highest for the sites in the CLoHAM model area. This would occur in Project Year 4 of construction and therefore forms part of the ‘project-wide’ peak activity scenario listed in para. 12.5.50a above

d. one scenario representing the month in which the aggregate average daily construction lorry movements would be highest for the sites in the ELHAM model area. This would occur in Project Year 4 of construction and therefore forms part of the ‘project-wide’ peak activity scenario listed in para. 12.5.50a above.

12.5.51 The project-wide peak month coincides with the cluster peak months in which construction lorry movements at the groups of sites in CLoHAM and ELHAM would be at their highest. The cluster peak month in WeLHAM would be earlier.

12.5.52 Vol 3 Table 12.5.3 shows the number of construction vehicle movements in the project-wide and cluster peak months. The assessment has been based on 10% of the daily number of lorry journeys occurring in the peak hours, which has been agreed with TfL as a reasonable approach.

Vol 3 Table 12.5.3 Transport – average daily construction lorry movements in peak months

Sites	Model area (West, Central, East)	Average daily construction lorry movements	
		Project-wide, central, east cluster peaks (Project Year 4 of construction)	West cluster peak (Project Year 2 of construction)
Acton Storm Tanks	West	10	0
Hammersmith Pumping Station	West	24	26
Barn Elms	West	10	22
Putney Embankment Foreshore	West	16	4
Carnwath Road Riverside	West	88	80
Dormay Street	West	10	50
King Georges Park	West	2	6
Falconbrook Pumping Station	Central	36	0
Cremorne Wharf Depot Site	Central	12	0
Chelsea Embankment Foreshore	Central	8	4

Sites	Model area (West, Central, East)	Average daily construction lorry movements	
		Project-wide, central, east cluster peaks (Project Year 4 of construction)	West cluster peak (Project Year 2 of construction)
Kirtling Street	Central	190	20
Heathwall Pumping Station	Central	12	16
Albert Embankment Foreshore	Central	26	34
Victoria Embankment Foreshore	Central	10	10
Blackfriars Bridge Foreshore	Central	14	46
Chambers Wharf	East	78	20
Shad Thames Pumping Station	East	4	0
King Edward Memorial Park Foreshore	East	16	12
Bekesbourne Street	East	0	0
Earl Pumping Station	East	4	68
Deptford Church Street	East	18	10
Greenwich Pumping Station	East	154	8
Abbey Mills Pumping Station	East	136	0
Beckton Sewage Treatment Works	East	6	38
Total		884	474

12.5.53 In addition to the construction lorry movements, allowance has been made for journeys made by operational vehicles travelling to and from sites during the working day. These are assumed to be constant across the construction programme at each site. They include activities such as worker shuttle bus movements to and from local stations, visits by client and contractor supervisors and other workers and small deliveries and maintenance (such as post and office supplies).

12.5.54 Para. 12.5.4 explains that whilst the *Draft Project Framework Travel Plan* which accompanies the application and the site-specific *Travel plan* measures would seek to minimise the number of construction worker journeys made by car, the assessment has assumed that at certain sites workers may drive, in order to ensure a robust analysis. These journeys have also been included in the strategic modelling.

12.5.55 Vol 3 Table 12.5.4 and Vol 3 Table 12.5.5 show the anticipated number of construction lorry, operational vehicle and worker car trips at each site during the AM and PM peak hours for the project-wide and cluster peak scenarios respectively.

12.5.56 Vol 3 Figure 12.5.1, Vol 3 Figure 12.5.2 and Vol 3 Figure 12.5.3 (see separate volume of figures) show the OmniTrans assignment of construction traffic to the London-wide network for the project-wide peak scenario. Vol 3 Figure 12.5.4 (see separate volume of figures) shows the OmniTrans assignment of construction traffic to WeLHAM for the western cluster peak scenario.

Vol 3 Table 12.5.4 Transport – project-wide peak and central and eastern cluster peak, construction vehicle movements (Project Year 4 of construction)

Site	AM peak hour				PM peak hour			
	Lorries*	Op veh**	Worker car***	Total	Lorries	Op veh	Worker car	Total
Acton Storm Tanks	1	5	19	25	1	5	19	25
Hammersmith Pumping Station	2	5	0	7	2	55	0	7
Barn Elms	1	5	0	6	1	5	0	6
Putney Embankment Foreshore	2	5	0	7	2	5	0	7
Carnwath Road Riverside	9	7	63	79	9	7	40	56
Dormay Street	1	5	28	34	1	5	28	34
King Georges Park	0	5	0	5	0	5	0	5
Falconbrook Pumping Station	4	5	16	25	4	5	16	25
Cremorne Wharf Depot Site	1	5	0	6	1	5	0	6
Chelsea Embankment Foreshore	1	5	0	6	1	5	0	6
Kirtling Street	19	7	0	26	19	7	0	26
Heathwall Pumping Station	1	5	0	6	1	5	0	6
Albert Embankment Foreshore	3	5	0	8	3	5	0	8
Victoria Embankment Foreshore	1	5	0	6	1	5	0	6
Blackfriars Bridge Foreshore	1	5	0	6	1	5	0	6
Chambers Wharf	8	7	0	15	8	7	0	15
Shad Thames Pumping Station	1	5	0	6	1	5	0	6

Site	AM peak hour				PM peak hour			
	Lorries*	Op veh**	Worker car***	Total	Lorries	Op veh	Worker car	Total
King Edward Memorial Park Foreshore	2	5	0	7	2	5	0	7
Bekesbourne Street	0	0	0	0	0	0	0	0
Earl Pumping Station	0	5	21	26	0	5	21	26
Deptford Church Street	2	5	20	27	2	5	20	27
Greenwich Pumping Station	15	7	0	22	15	7	0	22
Abbey Mills Pumping Station	14	5	24	43	14	5	24	43
Beckton Sewage Treatment Works	1	5	27	33	1	5	27	33
Total	90	123	218	431	90	123	195	408

Notes: The assessment has been based on 10% of daily construction lorry movements associated with materials taking place in each of the peak hours
**Lorries: construction lorries (HGV) associated with each project site*
***Op veh: operational vehicles including those used by contractors staff (eg, supervisors) moving between sites; worker shuttle bus transport; small deliveries (eg, office supplies)*
****Worker car: number of cars used by workers to travel to and from sites, based on an unconstrained assessment at sites where parking is unrestricted and capacity is available in the surrounding area, or where worker parking would be provided on site (Beckton Sewage Treatment Works). These figures have been adopted to ensure a robust assessment and in practice the lack of worker parking on site and measures in the Draft Project Framework Travel Plan which accompanies the application and site-specific Travel Plans would mean that in practice it is highly unlikely that workers would drive to these sites.*

Vol 3 Table 12.5.5 Transport – western cluster peak, construction vehicle movements (Project Year 2 of construction)

Site	AM peak hour				PM peak hour			
	Lorries*	Op veh**	Worker car***	Total	Lorries	Op veh	Worker car	Total
Acton Storm Tanks	0	0	0	0	0	0	0	0
Hammersmith Pumping Station	3	5	0	8	3	5	0	8
Barn Elms	2	5	0	7	2	5	0	7
Putney Embankment Foreshore	1	5	0	6	1	5	0	6
Carnwath Road Riverside	8	7	63	78	8	7	40	55
Dormay Street	5	5	28	38	5	5	28	38
King Georges Park	1	5	0	6	1	5	0	6
Falconbrook Pumping Station	0	0	0	0	0	0	0	0
Cremorne Wharf Depot Site	0	0	0	0	0	0	0	0
Chelsea Embankment Foreshore	0	5	0	5	0	5	0	5
Kirtling Street	2	7	0	9	2	7	0	9
Heathwall Pumping Station	2	5	0	7	2	5	0	7
Albert Embankment Foreshore	3	5	0	8	3	5	0	8
Victoria Embankment Foreshore	1	5	0	6	1	5	0	6
Blackfriars Bridge Foreshore	5	5	0	10	5	5	0	10
Chambers Wharf	2	7	0	9	2	7	0	9
Shad Thames Pumping Station	0	0	0	0	0	0	0	0
King Edward Memorial Park	1	5	0	6	1	5	0	6

Site	AM peak hour				PM peak hour			
	Lorries*	Op veh**	Worker car***	Total	Lorries	Op veh	Worker car	Total
Foreshore								
Bekesbourne Street	0	0	0	0	0	0	0	0
Earl Pumping Station	7	5	21	32	7	5	21	32
Deptford Church Street	1	5	20	26	1	5	20	26
Greenwich Pumping Station	1	7	0	8	1	7	0	8
Abbey Mills Pumping Station	0	0	0	0	0	0	0	0
Beckton Sewage Treatment Works	4	5	27	36	4	5	27	36
Total	49	98	159	306	49	98	136	283

Notes: The assessment has been based on 10% of daily construction lorry movements associated with materials taking place in each of the peak hours.
**Lorries: construction lorries (HGV) associated with each project site.*
***Op veh: operational vehicles including those used by contractors staff (eg, supervisors) moving between sites; worker shuttle bus transport; small deliveries (eg, office supplies)*
****Worker car: number of cars used by workers to travel to and from sites, based on an unconstrained assessment at sites where parking is unrestricted and capacity is available in the surrounding area, or where worker parking would be provided on site (Beckton Sewage Treatment Works). These figures have been adopted to ensure a robust assessment and in practice the lack of worker parking on site and measures in the Draft Project Framework Travel Plan which accompanies the application and site-specific Travel plans would mean that in practice it is highly unlikely that workers would drive to these sites.*

12.5.57 Vol 3 Table 12.5.4 shows that in for the project-wide peak activity scenario, approximately 430 vehicle movements would be expected in the AM peak hour in total, across the London highway network, as a result of activity at all of the Thames Tideway Tunnel project sites that would be active at that point in the programme. The corresponding figure for the PM peak hour would be around 410 vehicles. This includes the allowance for workers travelling by car to certain sites, which is a robust assessment given that this would be discouraged through the *Draft Project Framework Travel Plan* (which accompanies the application) and site-specific *Travel plans*.

12.5.58 Vol 3 Table 12.5.5 shows that for the western cluster peak scenario, approximately 300 and 280 vehicle movements would be expected in total in the AM and PM peak hours respectively across the London highway network.

Assessment of highway network effects

12.5.59 The relevant criteria for determining the magnitude of impacts on the highway network and operation are road network delay, accidents and safety and hazardous loads, as set out in Vol 2 Section 12.

Road network delay

12.5.60 The assessment of road network delay is based on the results of the strategic modelling using the HAMs.

12.5.61 It is useful to compare the key model statistics from the construction development case scenarios against the construction base case as this gives an overall summary of the degree of change that could be expected.

12.5.62 Vol 3 Table 12.5.6 and Vol 3 Table 12.5.7 present the key statistics for the project-wide AM and PM peak hour modelling respectively. This also covers the central and eastern cluster peaks, which occur at the same point in the programme.

12.5.63 In the AM peak hour, the statistics show small increases in the total travel time within each of the three modelled areas. In all cases this increase would be less than 0.5% over the construction base case. Average speeds in WeLHAM and ELHAM area would not change and there would be a marginal reduction in average speed in CLoHAM area.

12.5.64 In the PM peak hour, a similar pattern would occur, with small changes of less than 0.5% in overall travel time (including a marginal reduction for WeLHAM). Average speeds would increase slightly in WeLHAM area, remain static in CLoHAM area and reduce slightly in ELHAM area.

Vol 3 Table 12.5.6 Transport – highway network statistics, project-wide peak and central and eastern cluster peak, AM peak hour (Project Year 4 of construction)

Model	Transient queues[a]	Over-capacity queues[b]	Link cruise times[c]	Total travel time[d]	Travel distance[e]	Average speed[f]
	pcu[g]-hrs	pcu-hrs	hours	pcu-hrs	pcu-km	km/h
WeLHAM						
Base case	26,253	13,458	66,155	105,867	3,454,429	32.6
Devt case	26,292	13,574	66,211	106,077	3,456,492	32.6
Change	0.15%	0.86%	0.08%	0.20%	0.06%	0.00%
CLoHAM						
Base case	13,637	3,193	20,249	37,078	666,664	18.0
Devt case	13,680	3,258	20,273	37,211	667,278	17.9
Change	0.32%	2.05%	0.12%	0.36%	0.09%	-0.56%
ELHAM						
Base case	23,663	9,099	62,277	95,039	3,089,251	32.5
Devt case	23,747	9,188	62,384	95,319	3,093,366	32.5
Change	0.35%	0.97%	0.17%	0.29%	0.13%	0.00%

a) Transient queues – total time spent in 'under-capacity' queues (eg, queues which form at a red signal but dissipate during the following green period)
b) Over-capacity queues – total time spent in queues which form due to lack of capacity (eg, queues which form at a red signal but do not clear in the following green period)
c) Total link cruise time – total time spent travelling along links within the modelled network, excluding time spent queuing
d) Total travel time – sum of transient queue, over-capacity queue and link cruise times
e) Total travel distance – total distance travelled by all vehicles within the model network during the modelled period
f) Average speed – speed of vehicles averaged across the whole network and the whole modelled period (total travel distance / total travel time)
g) pcu – passenger car unit; a unit representing the equivalent of one car. Different vehicle types have different pcu values (eg, car = one pcu, vans and three-axle vehicles = 1.5 pcu, buses and coaches = two pcu, four-axle vehicles = 2.3 pcu)

Vol 3 Table 12.5.7 Transport – highway network statistics, project-wide peak and central and eastern cluster peak, PM peak hour (Project Year 4 of construction)

Model	Transient queues[a]	Over-capacity queues[b]	Link cruise times[c]	Total travel time[d]	Travel distance[e]	Average speed[f]
	pcu[g]-hrs	pcu-hrs	hours	pcu-hrs	pcu-km	km/h
WeLHAM						
Base case	27,671	18,063	67,501	113,235	3,508,154	31.0
Devt case	27,624	17,921	67,495	113,040	3,510,129	31.1
Change	-0.17%	-0.79%	-0.01%	-0.17%	0.06%	0.32%
CLoHAM						
Base case	12,786	3,713	19,602	36,101	639,045	17.7
Devt case	12,820	3,724	19,630	36,175	639,867	17.7
Change	0.27%	0.30%	0.14%	0.20%	0.13%	0.00%
ELHAM						
Base case	24,192	10,997	61,588	96,778	3,067,299	31.7
Devt case	24,275	11,167	61,656	97,097	3,069,979	31.6
Change	0.34%	1.54%	0.11%	0.33%	0.09%	-0.32%

a) Transient queues – total time spent in 'under-capacity' queues (eg, queues which form at a red signal but dissipate during the following green period)
b) Over-capacity queues – total time spent in queues which form due to lack of capacity (eg, queues which form at a red signal but do not clear in the following green period)
c) Total link cruise time – total time spent travelling along links within the modelled network, excluding time spent queuing
d) Total travel time – sum of transient queue, over-capacity queue and link cruise times
e) Total travel distance – total distance travelled by all vehicles within the model network during the modelled period
f) Average speed – speed of vehicles averaged across the whole network and the whole modelled period (total travel distance / total travel time)
g) pcu – passenger car unit; a unit representing the equivalent of one car. Different vehicle types have different pcu values (eg, car = one pcu, vans and three-axle vehicles = 1.5 pcu, buses and coaches = two pcu, four-axle vehicles = 2.3 pcu)

12.5.65 Vol 3 Table 12.5.8 presents the statistics for the WeLHAM cluster peak for both AM and PM peak hours. This again shows a similar pattern to the results for the project-wide and central and eastern cluster peak hours, with very small increases to the total travel time in the model and no significant change to average speeds.

12.5.66 These overall statistics indicate that at a strategic level, the impact of construction traffic associated with the project would be extremely small.

12.5.67 It is acknowledged that at the local level in the vicinity of individual sites, the impact of construction traffic on individual junctions near the site accesses may be more significant and this has been assessed as part of the site-specific assessments described in Section 12 of Vols 4 to 27.

Vol 3 Table 12.5.8 Transport – highway network statistics, western cluster peak (Project Year 2 of construction)

Model	Transient queues[a]	Over-capacity queues[b]	Link cruise times[c]	Total travel time[d]	Travel distance[e]	Average speed[f]
	pcu[g]-hrs	pcu-hrs	hours	pcu-hrs	pcu-km	km/h
AM peak hour						
Base case	26,253	13,458	66,155	105,867	3,454,429	32.6
Devt case	26,263	13,517	66,198	105,977	3,455,671	32.6
Change	0.04%	0.43%	0.06%	0.10%	0.04%	0.00%
PM peak hour						
Base case	27,671	18,063	67,501	113,235	3,508,154	31.0
Devt case	27,660	18,313	67,443	113,416	3,507,864	30.9
Change	-0.04%	1.38%	-0.09%	0.16%	-0.01%	-0.32%

a) Transient queues – total time spent in 'under-capacity' queues (eg,. queues which form at a red signal but dissipate during the following green period)
b) Over-capacity queues – total time spent in queues which form due to lack of capacity (eg, queues which form at a red signal but do not clear in the following green period)
c) Total link cruise time – total time spent travelling along links within the modelled network, excluding time spent queuing
d) Total travel time – sum of transient queue, over-capacity queue and link cruise times
e) Total travel distance – total distance travelled by all vehicles within the model network during the modelled period
f) Average speed – speed of vehicles averaged across the whole network and the whole modelled period (total travel distance / total travel time)
g) pcu – passenger car unit; a unit representing the equivalent of one car. Different vehicle types have different pcu values (eg, car = one pcu, vans and three-axle vehicles = 1.5 pcu, buses and coaches = two pcu, four-axle vehicles = 2.3 pcu)

12.5.68 The outputs from each of the models have been interrogated to identify where changes in delay would fall within the thresholds set out in the road network delay impact magnitude criteria in Vol 2 Section 12.

12.5.69 It must be noted that the nature of the strategic models is to undertake dynamic reassignment of traffic within each model run on the basis of modelled delays and journey times. This occurs unless assignments have been fixed, as has been the case for Thames Tideway Tunnel construction lorries in this assessment. This means that changes may occur anywhere in the model each time the model is run and may not be directly due to the additional demand that has been introduced to the model. This is particularly important when the additional demand is small in comparison to the size of the network and volume of traffic, as is the case for this assessment.

12.5.70 The delay changes described below have therefore been reviewed to determine whether they appear to arise as a direct result of the additional project construction traffic that has been added for the construction development case, or whether they are due to these 'internal' modelling effects.

12.5.71 Vol 3 Table 12.5.9 and Vol 3 Table 12.5.10 present the delay changes which are of low or greater magnitude (based on the criteria in Vol 2 Section 12) for the project-wide AM and PM peak hours. This also represents the changes for the central and eastern cluster peaks.

12.5.72 Vol 3 Table 12.5.9 shows that in the project-wide AM peak hour, there would be two links experiencing a low adverse impact on delay. However, one of these links is on the outer edge of WeLHAM and the impact is not directly related to additional construction traffic from the project. The other, within CLoHAM, lies on a route that would be used by project construction traffic and this may therefore contribute to the change in delay at that location. There would also be one location experiencing a low beneficial impact.

12.5.73 Vol 3 Table 12.5.10 shows that in the project-wide PM peak hour there would be two locations in WeLHAM where low adverse impacts on delays would be experienced. However, analysis of the model suggests that the change in both these locations is likely to be due to other reassignment taking place within the model and not as a direct result of the project construction traffic. There would also be four locations in WeLHAM and one location in CLoHAM experiencing a low beneficial impact and one location in WeLHAM experiencing a medium beneficial impact.

12.5.74 Vol 3 Table 12.5.11 and Vol 3 Table 12.5.12 show the AM and PM peak hour information for the western cluster peak scenario, which has been tested in WeLHAM. The tables show that in the AM peak, one location would experience a low adverse impact, which may be influenced by project construction traffic using that route, and one would experience a low beneficial impact.

12.5.75 In the PM peak hour, Vol 3 Table 12.5.12 shows that there would be three locations in WeLHAM experiencing a low adverse impact, one experiencing a medium adverse impact and one experiencing a high adverse impact. Analysis of the model outputs suggests that the low and medium adverse impacts are not directly related to project construction traffic. The high adverse impact appears to occur as a result of dynamic traffic reassignment within the model for other reasons, as there would only be three construction vehicles per hour associated with the project passing through this location.

12.5.76 Vol 3 Table 12.5.12 also shows that in the western cluster PM peak hour there would be one location experiencing a low beneficial impact and one experiencing a medium beneficial impact.

12.5.77 Bearing in mind that these results show only a small number of locations where delay changes are not negligible, and the overall indications from the key model statistics in paras. 12.5.61 to 12.5.67, the overall impact on road network delay at the strategic level has been assessed as negligible.

Vol 3 Table 12.5.9 Transport – changes in modelled delay, project-wide peak and central and eastern cluster peak, AM peak hour (Project Year 4 of construction)

Model	Impact magnitude	Beneficial / adverse	Change in delay (seconds)	Node no.	Location	Comment
W	Low	Adverse	+61	91606	Watford Road / North Western Avenue (A41) (Hertfordshire)	No project construction vehicles on this route. Minor route switching occurring at base case overcapacity junction. Change due to modelling effect and not directly related to project.
W	Low	Beneficial	-79	34268	Chelsea Embankment / Royal Hospital Road (Kensington and Chelsea)	
C	Low	Adverse	+66	27992	Jamaica Road / Lower Road / Brunel Road Roundabout (Southwark)	Delay is caused by blocking back from roundabout. There are an additional seven construction vehicles on this route in the AM peak hour, which may contribute to the increase in delay.
E	-	-	None	None	None	

Note: Table shows only delay changes which are in excess of one minute.
The reasons for reductions in delay within the HAMs development cases have not been investigated in detail as they are typically the result of dynamic reassignment taking place within the model simulation and not directly attributable to the additional construction traffic within the models in the development case.

Vol 3 Table 12.5.10 Transport – changes in modelled delay, project-wide peak and central and eastern cluster peak, PM peak hour (Project Year 4 of construction)

Model	Impact magnitude	Beneficial / adverse	Change in delay (seconds)	Node no.	Location	Comment
W	Low	Adverse	+75	70343	Entry on to Brent Cross Interchange (A41) from Haley Road (Barnet)	Local re-routing occurring in the model, due to modelling effect and not directly related to project.
W	Low	Adverse	+82	30051	Kingston Road / Roehampton Lane (Wandsworth)	Only one project construction vehicle assigned to this route in the PM peak hour. Change due to modelling effect and not directly related to project.
W	Low	Beneficial	-61	70245	Edgware Road / Broadfields Avenue (Barnet)	
W	Low	Beneficial	-98	32202	Shepherds Bush Green / Rockley Road (Hammersmith and Fulham)	
W	Low	Beneficial	-105	60331	Hogarth Lane entry to Hogarth Roundabout (Hounslow)	
W	Low	Beneficial	-105	91021	Latchmere Road / Elspeth Road / Lavender Hill (Wandsworth)	
W	Medium	Beneficial	-151	59095	Chertsey Road on to Hospital Bridge Roundabout (Richmond)	
C	Low	Beneficial	-85	12380	St Johns Wood Road / Lisson Grove / Grove	

Model	Impact magnitude	Beneficial / adverse	Change in delay (seconds)	Node no.	Location	Comment
					End Road (Westminster)	
E	-	-	None	None	None	

Note: Table shows only delay changes which are in excess of one minute. The reasons for reductions in delay within the HAMs development cases have not been investigated in detail as they are typically the result of dynamic reassignment taking place within the model simulation and not directly attributable to the additional construction traffic within the models in the development case.

Vol 3 Table 12.5.11 Transport – changes in modelled delay, western cluster peak, AM peak hour (Project Year 2 of construction)

Model	Impact magnitude	Beneficial / adverse	Change in delay (seconds)	Node no.	Location	Comment
W	Low	Adverse	+87	60122	Wellesley Road (A3000) / North Circular Road (Hounslow)	Delays caused by blocking back from downstream junction, which may be affected by small flow increase on this route due to project construction traffic.
W	Low	Beneficial	-79	34268	Chelsea Embankment / Royal Hospital Road (Kensington and Chelsea)	

Note: Table shows only delay changes which are in excess of one minute.
The reasons for reductions in delay within the HAMs development cases have not been investigated in detail as they are typically the result of dynamic reassignment taking place within the model simulation and not directly attributable to the additional construction traffic within the models in the development case.

Vol 3 Table 12.5.12 Transport – changes in modelled delay, western cluster peak, PM peak hour (Project Year 2 of construction)

Model	Impact magnitude	Beneficial / adverse	Change in delay (seconds)	Node no.	Location	Comment
W	Low	Adverse	+82	30051	Kingston Road / Roehampton Lane (Wandsworth)	Delay arising from re-routing within model. No project construction traffic on this route. Change due to modelling effect and not directly related to project.
W	Low	Adverse	+94	12621	South Audley Street / Curzon Street (Westminster)	Delay arising from small flow change related to blocking back from downstream junction. Change due to modelling effect and not directly related to project.
W	Low	Adverse	+102	12805	Bennett Street / Arlington Street (Westminster)	Delay arising from small flow change related to blocking back from downstream junction. Change due to modelling effect and not directly related to project.
W	Medium	Adverse	+225	91665	Cassio Road near West Hertfordshire Sports Ground (Hertfordshire)	Local re-routing within model increases delay at an already overcapacity junction. No project construction traffic on this route. Change due to modelling effect and not directly related to project.
W	High	Adverse	+363	60331	Hogarth Lane entry to Hogarth Roundabout (Hounslow)	Delay caused by significant re-routing within model from other radial routes. Project construction traffic on this route is only three vehicles. Change likely to be due to modelling effect and not

Model	Impact magnitude	Beneficial / adverse	Change in delay (seconds)	Node no.	Location	Comment
						directly related to project.
W	Low	Beneficial	-61	91647	Vicarage Road/A411 Watford (Hertfordshire)	
W	Medium	Beneficial	-151	59095	Chertsey Road on to Hospital Bridge Roundabout (Richmond)	

Note: Table shows only delay changes which are in excess of one minute.
The reasons for reductions in delay within the HAMs development cases have not been investigated in detail as they are typically the result of dynamic reassignment taking place within the model simulation and not directly attributable to the additional construction traffic within the models in the development case.

Accidents and safety

12.5.78 For the project-wide assessment, a broad and high-level estimate has been made of the potential increase in the number of accidents that might occur on the highway network as a consequence of the additional HGV movements associated with the Thames Tideway Tunnel project.

12.5.79 The assessment was based on an estimate of the total number of kilometres likely to be travelled by construction lorries, whether in London or outside, based on the proposed *Transport Strategy* which accompanies the application. This was compared with historical data on the rate of accidents per billion HGV kilometres, provided by TfL.

12.5.80 It is recognised that this is a high level assessment which examines potential accident risk, rather than a definitive analysis which indicates that additional accidents would occur.

12.5.81 The site-specific assessments deal with local issues and risks in greater detail and measures contained within the *CoCP Part B* (Section 5) (see Vol 1 Appendix A) would ensure that all reasonable steps are taken to minimise the number of accidents involving construction vehicles associated with the project. This includes requirements that construction vehicles are fitted with 'active' cycle safety measures and that construction vehicle drivers are appropriately trained.

12.5.82 Using this approach, the assessment identified the potential for seven additional accidents to occur on the highway network over the life of the project. Based on the accident severity statistics, one of these seven accidents could be classified as serious and the remaining six as slight This represents approximately one accident per year of construction arising from the additional HGV kilometres travelled by project vehicles.

12.5.83 Statistics from TfL (Casualties in Greater London during 2011 (TfL, 2012)[13]) show that in 2011 there were over 24,400 road traffic collisions in London, leading to a total of 29,250 casualties.

12.5.84 In that context, bearing in mind that some project construction vehicles may also be travelling on the highway network outside London and given that the *CoCP* and associated measures would be put in place to maximise and ensure safety during construction, an increase of approximately seven accidents in total, or one per year, would not be statistically significant.

12.5.85 On this basis, the impact of the project on accidents and safety at a project-wide level would be negligible.

12.5.86 Site-specific accident and safety assessments have been undertaken for the area surrounding each of the construction sites and these are set out in Section 12 of Vols 4 to 27.

Hazardous loads

12.5.87 The site-specific assessments in Section 12 of Vols 4 to 27 identify the expected number of hazardous loads that would be associated with each site. These loads include fuel deliveries to all sites and the removal of treated hazardous material from a small number of sites. In summary the assessment is based on:

a. two hazardous loads per week at Kirtling Street, Chambers Wharf and Greenwich Pumping Station

b. one hazardous load per week at Carnwath Road Riverside

c. one hazardous load every fortnight at all other sites.

12.5.88 In total this represents approximately 17 hazardous loads per week on average serving the whole of the Thames Tideway Tunnel project.

12.5.89 The impact magnitude criteria in Vol 2 Section 12 have been used to assess the impact of hazardous load movements on a site-specific basis. The site-specific assessments in Vols 4 to 27 conclude that hazardous loads would present a medium adverse impact at four sites and a low adverse impact at the other 20 sites.

12.5.90 The construction sites would be spread across a wide area of the highway network and thus hazardous loads associated with sites would tend to be distributed across the highway network in London rather than concentrated on specific routes. It should also be noted that the majority of loads classified as hazardous in this assessment would be fuel deliveries, for which appropriate protective measures would be taken in any event as required by legislation. These include the use of appropriate vehicles and routes, the required warning signage on vehicles and procedures for managing incidents.

12.5.91 In this context, the project-wide assessment of the impact of hazardous loads has been based on considering the level of impact identified at construction sites, rather than the total number of hazardous loads generated by the project.

12.5.92 On the basis that the impact from hazardous loads has been assessed as low adverse at the majority of sites, the project-wide impact of hazardous loads has also been assessed as low adverse.

Sub-area analysis

12.5.93 The scope of the sub-area analysis on Victoria Embankment (A3211) is described in Section 12.3.

12.5.94 The VISSIM modelling provides an assessment of how the network on Victoria Embankment (A3211) would be affected by construction at Victoria Embankment Foreshore and Blackfriars Bridge Foreshore, with particular reference to changes in journey time over a number of route options through the modelled network.

12.5.95 As para. 12.3.51 explains, three scenarios have been modelled for the development case, reflecting the varying traffic management layouts at the two sites during their respective construction periods. The scenarios are:

a. Scenario 1 representing utility diversion works at Victoria Embankment Foreshore and the associated narrowing of the road past the site

b. Scenario 2 representing phase 1 and 2 works at Blackfriars Bridge Foreshore and the associated narrowing of the westbound slip road from Blackfriars Bridge (A201) to Victoria Embankment (A3211)

c. Scenario 3 representing phase 3 works at Blackfriars Bridge Foreshore and the associated closure of the westbound slip road.

12.5.96 In each case these scenarios include construction traffic associated with both these sites and traffic associated with any other Thames Tideway Tunnel sites that would use routes through the network modelled in the VISSIM model.

12.5.97 Vol 3 Table 12.5.13 and Vol 3 Table 12.5.14 show the journey time results for the base case and the three development case scenarios described in para. 12.5.95, for the AM and PM peak hours respectively.

12.5.98 For Scenario 1, Vol 3 Table 12.5.13 shows that in the AM peak hour the largest increase in journey time would be around 20 seconds on the route from Upper Thames Street (A3211) to Westminster Bridge (A302) in the westbound direction and is likely to be the result of the narrowing of Victoria Embankment (A3211) at the Victoria Embankment Foreshore site and the slight reduction in capacity at the junction of Victoria Embankment (A3211) and Horse Guards Avenue that this would cause.

12.5.99 Vol 3 Table 12.5.14 shows that in the PM peak hour for Scenario 1 any increases in journey times would be minimal and it is expected that journey times would either remain similar or reduce slightly compared to base case operation.

12.5.100 For Scenario 2 Vol 3 Table 12.5.13 shows that in the AM peak hour the largest journey time increase would be 34 seconds for vehicles travelling westbound between New Bridge Street (A201) and Northumberland Avenue. An increase of 23 seconds would occur for vehicles travelling westbound between New Bridge Street (A201) and Westminster Bridge (A302). This additional delay is most likely to arise from the amended highway layout on the westbound slip road from Blackfriars Bridge (A201) to Victoria Embankment (A3211). Journey times for other routes through the VISSIM network would experience very small changes.

12.5.101 In the PM peak hour for Scenario 2, Vol 3 Table 12.5.14 shows a similar pattern with the greatest increases in journey time experienced on the westbound routes between New Bridge Street (A201) and Northumberland Avenue and Westminster Bridge (A302), with increases of 43 and 22 seconds respectively. As for the AM peak hour this is most likely to result from the narrowing of the westbound slip road from Blackfriars Bridge (A201).

Vol 3 Table 12.5.13 Transport – VISSIM development case journey times, AM peak hour

Route		Direction	Modelled journey time (mm:ss)						
			Base case	Scenario 1	Change	Scenario 2	Change	Scenario 3	Change
Bridge Street (A302) to Upper Thames Street (A3211)	1	Eastbound	05:29	05:33	+00:04	05:30	+00:01	05:29	00:00
	2	Westbound	06:20	06:27	+00:07	06:12	-00:08	06:15	-00:05
Blackfriars Bridge (A201) to New Bridge Street (A201)	3	Northbound	01:42	01:38	-00:04	01:42	00:00	01:31	-00:11
	4	Southbound	01:21	01:21	00:00	01:21	00:00	01:08	-00:13
Northumberland Avenue to Upper Thames Street (A3211)	5	Eastbound	04:16	04:17	+00:01	04:17	+00:01	04:18	+00:02
	6	Westbound	04:32	04:32	00:00	04:28	-00:04	04:28	-00:04
Northumberland Avenue to New Bridge Street (A201)	7	Eastbound	04:44	04:45	+00:01	04:48	+00:04	04:50	+00:06
	8	Westbound	05:39	05:49	+00:10	06:13	+00:34	-	-
Westminster Bridge (A302) to New Bridge Street (A201)	9	Eastbound	06:37	06:34	-00:03	06:40	+00:03	06:42	+00:05
	10	Westbound	06:31	06:34	+00:03	06:54	+00:23	-	-
Upper Thames Street (A3211) to Westminster Bridge (A302)	11	Westbound	06:20	06:41	+00:21	06:25	+00:05	06:25	+00:05
	12	Eastbound	06:05	06:09	+00:04	06:10	+00:05	06:04	-00:01

Note: Routes 8 and 10 are not included in Scenario 3 due to the closure of the westbound on-slip at Victoria Embankment (A3211) / Blackfriars Bridge (A201).

Vol 3 Table 12.5.14 Transport – VISSIM development case journey times, PM peak hour

Route		Direction	Modelled journey time (mm:ss)						
			Base case	Scenario 1	Change	Scenario 2	Change	Scenario 3	Change
Bridge Street (A302) to Upper Thames Street (A3211)	1	Eastbound	05:55	05:55	00:00	05:47	-00:08	05:52	-00:03
	2	Westbound	06:56	06:54	-00:02	06:38	-00:14	06:12	-00:44
Blackfriars Bridge (A201) to New Bridge Street (A201)	3	Northbound	01:19	01:21	+00:02	01:20	+00:01	01:15	-00:04
	4	Southbound	01:05	01:05	00:00	01:05	00:00	01:00	-00:05
Northumberland Avenue to Upper Thames Street (A3211)	5	Eastbound	04:22	04:21	-00:01	04:14	-00:08	04:17	-00:05
	6	Westbound	05:10	05:08	-00:02	04:54	-00:16	04:35	-00:35
Northumberland Avenue to New Bridge Street (A201)	7	Eastbound	05:00	04:57	-00:03	04:37	-00:23	05:26	+00:26
	8	Westbound	06:21	06:18	-00:03	07:04	+00:43	-	-
Westminster Bridge (A302) to New Bridge Street (A201)	9	Eastbound	07:05	06:59	-00:06	06:49	-00:16	07:27	+00:22
	10	Westbound	07:27	07:24	-00:03	07:49	+00:22	-	-
Upper Thames Street (A3211) to Westminster Bridge (A302)	11	Westbound	08:07	07:51	-00:16	07:36	-00:31	07:16	-00:53
	12	Eastbound	06:39	06:36	-00:03	06:26	-00:13	06:30	-00:03

Note: Routes 8 and 10 are not included in Scenario 3 due to the closure of the westbound on-slip at Victoria Embankment (A3211) / Blackfriars Bridge (A201).

12.5.102 Vol 3 Table 12.5.13 shows that for Scenario 3 in the AM peak hour, journey time increases on the routes investigated would be less than ten seconds. Vol 3 Table 12.5.13 also shows that on the routes between New Bridge Street (A201) and Blackfriars Bridge (A201), the journey times would reduce compared to the base case. This can be attributed to a number of factors including the adjustments to the signal timings at the junction of these two roads and the reduction in the traffic flows resulting from traffic diverting to other routes because of the closure of the westbound slip road to Victoria Embankment (A3211).

12.5.103 For Scenario 3 in the PM peak hour Vol 3 Table 12.5.14 shows that there would be increases in journey times of 22 and 26 seconds on the eastbound routes between Northumberland Avenue and New Bridge Street (A201) and Westminster Bridge (A302) and New Bridge Street (A201) respectively. This is likely to reflect changes to signal timings on the eastbound slip road to New Bridge Street (A201) because of traffic flow changes arising from the closure of the westbound slip road. Journey times on the westbound routes would decrease in Scenario 3, which is likely to reflect a reduced level of traffic on Victoria Embankment (A3211) as a result of the closure of the westbound slip road.

12.5.104 In Scenario 3 the routes westbound between New Bridge Street (A201) and Northumberland Avenue and Westminster Bridge (A302) are not available within the VISSIM model because of the closure of the westbound slip road at Blackfriars Bridge (A201). As the VISSIM model does not cover the wider network, the journey times on alternative routes are not recorded. However, vehicles approaching from New Bridge Street (A201) would find alternative routes to the north and west, whilst vehicles approaching from Blackfriars Bridge (A201) would find alternative routes to the south.

12.5.105 Furthermore, the results of the strategic highway assessment using the HAMs, which are reported in paras. 12.5.60 to 12.5.77 and include the closure of the westbound slip road at Blackfriars Bridge (A201), show that there would be no changes to journey times of more than one minute on the wider network in this area.

12.5.106 The results from the VISSIM models show that under any of the development case scenarios tested for concurrent activity at Victoria Embankment Foreshore and Blackfriars Bridge Foreshore, the maximum increase in road network delay on any route through the modelled network would be less than one minute. The greatest increases occur over the longest routes (between Westminster Bridge (A302) and Blackfriars Bridge (A201) which represents a distance of approximately 2km.

12.5.107 Based on the criteria for assessing road network delay set out in Vol 2 Section 12, the changes in journey times shown by the VISSIM models equate to a negligible impact in both the AM and PM peak hours

Significance of effects

12.5.108 The significance of the project-wide effects has been determined by considering the transport impacts described above in the context of the sensitivity of the receptors identified in Vol 3 Table 12.4.2 which are present on the wider public transport, river and highway networks in London.

12.5.109 Vol 3 Table 12.5.15 sets out the effects on each receptor in relation to the overall project.

Vol 3 Table 12.5.15 Transport – significance of effects during construction

Receptors (relating to all identified transport effects)	Significance of effect	Justification
Private vehicle users travelling on the highway network in west, central and east London	**Project-wide:** **Negligible** effect **Sub area - Victoria Embankment (A3211) corridor:** **Negligible** effect	**Project-wide:** • Low to medium sensitivity • Negligible impact on road network delay • Negligible impact on accidents and safety • Low adverse impact on hazardous loads • Based on negligible and low adverse impacts, equates to an overall negligible effect. **Sub-area - Victoria Embankment (A3211) corridor:** • Low to medium sensitivity • Negligible impact on road network delay • Negligible impact on accidents and safety • Low adverse impact on hazardous loads • Based on negligible and low adverse impacts, equates to an overall negligible effect
Emergency vehicles travelling on the highway network in west, central and east London	**Project-wide:** **Negligible** effect **Sub area - Victoria Embankment (A3211) corridor:** **Negligible** effect	**Project-wide:** • High sensitivity • Negligible impact on road network delay • Negligible impact on accidents and safety • Low adverse impact on hazardous loads • Based on negligible and low adverse impacts, equates to an overall negligible effect

Receptors (relating to all identified transport effects)	Significance of effect	Justification
		Sub area - Victoria Embankment (A3211) corridor: • High sensitivity • Negligible impact on road network delay • Negligible impact on accidents and safety • Low adverse impact on hazardous loads • Based on negligible and low adverse impacts, equates to an overall negligible effect
Bus passengers and operators of bus services on the network in west, central and east London	**Project-wide:** **Negligible** effect **Sub area - Victoria Embankment (A3211) corridor:** **Negligible** effect	**Project-wide:** • Low to medium sensitivity • Negligible impact on road network delay • Negligible impact on patronage • Due to negligible impacts, equates to negligible effect **Sub area - Victoria Embankment (A3211) corridor:** • Low to medium sensitivity • Negligible impact on road network delay • Negligible impact on patronage • Due to negligible impacts, equates to negligible effect
Users of rail services on the network serving west, central and east London	**Negligible** effect	• Low sensitivity • Negligible impact on patronage • Due to negligible impact, equates to negligible effect
Users of river passenger services on the River Thames	**Negligible** effect	• Low to medium sensitivity • Negligible impact on patronage • Due to negligible impact,

Receptors (relating to all identified transport effects)	Significance of effect	Justification
		equates to negligible effect
Marine emergency services	**Negligible** effect upstream of Carnwath Road Riverside **Minor adverse** effect between Carnwath Road Riverside and Kirtling Street **Moderate adverse** effect downstream of Kirtling Street	• High sensitivity **Project-wide peak month of barge activity:** • Negligible impact upstream of Heathwall Pumping Station • Low adverse impact between Heathwall Pumping Station and Albert Embankment • Medium adverse impact downstream of Albert Embankment Foreshore **Other months:** • Negligible impact upstream of Kirtling Street • Medium adverse impact downstream of Kirtling Street • Considering impacts and durations of river activity over the project programme equates to a range of negligible, minor and moderate adverse effects.
Leisure users of the River Thames	**Negligible** effect upstream of Carnwath Road Riverside **Minor adverse** effect between Carnwath Road Riverside and Kirtling Street **Moderate adverse** effect downstream of Kirtling Street	• High sensitivity **Project-wide peak month of barge activity:** • Negligible impact upstream of Heathwall Pumping Station • Low adverse impact between Heathwall Pumping Station and Albert Embankment • Medium adverse impact downstream of Albert Embankment Foreshore **Other months:** • Negligible impact upstream of Kirtling Street • Medium adverse impact downstream of Kirtling Street

Receptors (relating to all identified transport effects)	Significance of effect	Justification
		• Considering impacts and durations of river activity over the project programme equates to a range of negligible, minor and moderate adverse effects.
River vessel operators	**Negligible** effect upstream of Carnwath Road Riverside **Minor adverse** effect between Carnwath Road Riverside and Kirtling Street **Moderate adverse** effect downstream of Kirtling Street	• Medium sensitivity **Project-wide peak month of barge activity:** • Negligible impact upstream of Heathwall Pumping Station • Low adverse impact between Heathwall Pumping Station and Albert Embankment • Medium adverse impact downstream of Albert Embankment Foreshore **Other months:** • Negligible impact upstream of Kirtling Street • Medium adverse impact downstream of Kirtling Street • Considering impacts and durations of river activity over the project programme equates to a range of negligible, minor and moderate adverse effects.

12.6 Operational effects assessment

12.6.1 As explained in Section 12.1 there is no need to undertake an assessment of project-wide operational effects as maintenance activities would be temporary and short-term and would involve an extremely small number of vehicle journeys.

12.7 Cumulative effects assessment

Construction effects

12.7.1 As para. 12.3.24 explains, there are no specific project-wide cumulative effects to assess, as the TfL HAMs being used for the assessment already take into account a level of future growth in employment and population across London, based on the proposals set out in the London Plan (GLA, 2011)[14].

12.8 Mitigation

12.8.1 The project has been designed to limit the effects on the transport networks as far as possible and many measures have been embedded directly in the design of the project including the *Transport Strategy,* which accompanies the application, and the *CoCP Part A and Part B* (Section 5) (see Vol 1 Appendix A).

12.8.2 During construction it is envisaged that those embedded measures would minimise the project-wide effects resulting from the construction phase of the project. These are the most appropriate measures at the project-wide level and it is not possible to mitigate all significant effects.

12.8.3 No assessment is required for the operational phase at a project-wide level.

12.9 Residual effects assessment

Construction effects

12.9.1 As no mitigation measures are proposed, the residual construction effects remain as described in Section 12.5. All residual effects are presented in Section 12.10.

12.10 Project-wide effects assessment summary

Vol 3 Table 12.10.1 Transport – summary of construction assessment

Receptor	Effect	Significance of effect	Mitigation	Significance of residual effect
Private vehicle users travelling on the highway network in west, central and east London	• Movement of large construction vehicles • Highway capacity changes • Delay to journey times at a small number of locations	**Project-wide:** Negligible effect **Sub area - Victoria Embankment (A3211) corridor:** Negligible effect	None	**Project-wide:** Negligible effect **Sub area - Victoria Embankment (A3211) corridor:** Negligible effect
Emergency vehicles travelling on the highway network in west, central and east London	• Movement of large construction vehicles • Highway capacity changes • Delay to journey times at a small number of locations	**Project-wide:** Negligible effect **Sub area - Victoria Embankment (A3211) corridor:** Negligible effect	None	**Project-wide:** Negligible effect **Sub area - Victoria Embankment (A3211) corridor:** Negligible effect
Bus passengers and operators of bus services on the network in west, central and east London	• Highway capacity changes • Delay to journey times • Some additional patronage from construction workers	**Project-wide:** Negligible effect **Sub area - Victoria Embankment (A3211) corridor:** Negligible effect	None	**Project-wide:** Negligible effect **Sub area - Victoria Embankment (A3211) corridor:** Negligible effect
Users of rail services on the network serving west, central and	• Some additional patronage from construction workers	Negligible effect	None	Negligible effect

Receptor	Effect	Significance of effect	Mitigation	Significance of residual effect
east London				
Users of river passenger services on the River Thames	• Some additional patronage from construction workers	Negligible effect	None	Negligible effect
Marine emergency services	• Additional barge movement on the River Thames	Negligible effect upstream of Carnwath Road Riverside Minor adverse effect between Carnwath Road Riverside and Kirtling Street Moderate adverse effect downstream of Kirtling Street	None	Negligible effect upstream of Carnwath Road Riverside Minor adverse effect between Carnwath Road Riverside and Kirtling Street Moderate adverse effect downstream of Kirtling Street
Leisure users of the River Thames	• Additional barge movement on the River Thames	Negligible effect upstream of Carnwath Road Riverside Minor adverse effect between Carnwath Road Riverside and Kirtling Street Moderate adverse effect downstream of Kirtling Street	None	Negligible effect upstream of Carnwath Road Riverside Minor adverse effect between Carnwath Road Riverside and Kirtling Street Moderate adverse effect downstream of Kirtling Street
River vessel operators	• Additional barge movement on the River Thames	Negligible effect upstream of Carnwath Road Riverside Minor adverse effect	None	Negligible effect upstream of Carnwath Road Riverside Minor adverse effect between Carnwath Road

Receptor	Effect	Significance of effect	Mitigation	Significance of residual effect
		between Carnwath Road Riverside and Kirtling Street Moderate adverse effect downstream of Kirtling Street		Riverside and Kirtling Street Moderate adverse effect downstream of Kirtling Street

12.11 Summary of significant effects at all sites

12.11.1 Significant adverse transport effects have been identified at nine sites as a result of construction activities. Vol 3 Table 12.11.1 provides a summary of the significant effects identified at individual sites across the project.

12.11.2 No significant adverse transport effects are predicted during the operation of the Thames Tideway Tunnel project.

12.11.3 The effects presented in Vol 3 Table 12.11.1 below represent a summary of the site specific effects presented in Section 12 of Vols 4 to 27, and do not constitute additional effects arising from the proposed development.

Vol 3 Table 12.11.1 Transport – summary of significant effects at all sites

Significance of effect	Receptor	Description of effect	Sites with significant effects (pre-mitigation)	Sites with significant residual effects
Construction - adverse	Pedestrians and cyclists using routes in the vicinity (including the Thames Path where applicable)	Effects on pedestrians and cyclists such as loss of footway/cycleway, local diversions, delay in journey time, relocation of crossing points and potential conflicts with construction traffic	Kirtling Street (pedestrians only) (see Vol 14 Section 12)	Kirtling Street (pedestrians only) (see Vol 14 Section 12)
			Albert Embankment Foreshore (pedestrians only) (see Vol 16 Section 12)	Albert Embankment Foreshore (pedestrians only) (see Vol 16 Section 12)
			Victoria Embankment Foreshore (pedestrians only) (see Vol 17 Section 12)	Victoria Embankment Foreshore (pedestrians only) (see Vol 17 Section 12)
			Blackfriars Bridge Foreshore (see Vol 18 Section 12)	Blackfriars Bridge Foreshore (see Vol 18 Section 12)
			Bekesbourne Street (pedestrians only) (see Vol 27 Section 12)	Bekesbourne Street (pedestrians only) (see Vol 27 Section 12)
			Deptford Church Street (pedestrians only) (see Vol 23 Section 12)	Deptford Church Street (pedestrians only) (see Vol 23 Section 12)
			Chelsea Embankment Foreshore (pedestrians only) (see Vol 13 Section 12)	Chelsea Embankment Foreshore (pedestrians only) (see Vol 13 Section 12)

Significance of effect	Receptor	Description of effect	Sites with significant effects (pre-mitigation)	Sites with significant residual effects
	Users of car parking	Effects on on-street parking users such as temporary restriction and/or relocation of parking spaces and use of local parking by construction workers	Acton Storm Tanks (only along Canham Road, Warple Way and Stanley Gardens) (see Vol 4 Section 12) Putney Embankment Foreshore (only during Putney Embankment secondary site construction) (see Vol 7 Section 12) Albert Embankment Foreshore (Option B only – parking users of Camelford House and Tintagel House) (see Vol 16 Section 12) Bekesbourne Street (see Vol 27 Section 12)	Acton Storm Tanks (only along Canham Road, Warple Way and Stanley Gardens) (see Vol 4 Section 12) Putney Embankment Foreshore (only during Putney Embankment secondary site construction) (see Vol 7 Section 12) Albert Embankment Foreshore (Option B only – parking users of Camelford House and Tintagel House) (see Vol 16 Section 12) Bekesbourne Street (see Vol 27 Section 12)

Significance of effect	Receptor	Description of effect	Sites with significant effects (pre-mitigation)	Sites with significant residual effects
	Coaches and service vehicles using parking facilities and loading bays	Effects on coaches and service vehicles such as temporary restriction and/or relocation of parking spaces/loading bays	Acton Storm Tanks (service vehicles) (see Vol 4 Section 12) Victoria Embankment Foreshore (see Vol 17 Section 12) Blackfriars Bridge Foreshore (coaches) (see Vol 18 Section 12) Bekesbourne Street (service vehicles) (see Vol 27 Section 12)	Acton Storm Tanks (service vehicles) (see Vol 4 Section 12) Victoria Embankment Foreshore (see Vol 17 Section 12) Blackfriars Bridge Foreshore (coaches) (see Vol 18 Section 12) Bekesbourne Street (service vehicles) (see Vol 27 Section 12)
	Passengers using Blackfriars Millennium Pier	Increased journey time for pedestrians	Blackfriars Bridge Foreshore (see Vol 18 Section 12)	Blackfriars Bridge Foreshore (see Vol 18 Section 12)
Operational – beneficial	Pedestrians using the Thames Path and new public realm	New public realm area	Albert Embankment Foreshore (see Vol 16 Section 12)	Albert Embankment Foreshore (see Vol 16 Section 12)

Note: The summary table reports the significant transport effects for key groups of transport users using the local transport networks in the vicinity of the Thames Tideway Tunnel sites. Effects at site-specific receptors are not reported (see Vols 4-27 for site-specific effects) but effects at such receptors would be no worse that the effects identified for the above groups of transport users.

References

[1] Transport for London (TfL). *Travel Planning for new development in London*, (2011).

[2] Transport for London. *Assessment Tool for Travel Plan Building Testing and Evaluation, (ATTrBuTE).* Available at: http://www.attrbute.org.uk/. Last accessed December 2012.

[3] Greater London Authority, *The London Plan – Spatial Development Strategy for London* (2011).

[4] Transport for London. *Travel in London, Report 4*. (2011).

[5] Transport for London, 2011. See citation above.

[6] Transport for London, 2011. See citation above.

[7] Docklands Light Railway website. Available at: http://www.tfl.gov.uk/corporate/modesoftransport/1530.aspx . Last accessed December 2012.

[8] Transport for London, 2011. See citation above.

[9] HM Government, *Traffic Management Act 2004* (2004).

[10] Transport for London. *London Underground Upgrade Plan*, (2011).

[11] Greater London Authority, 2011. See citation above.

[12] Greater London Authority, 2011. See citation above.

[13] Transport for London. *Casualties in Greater London during 2011 (factsheet)*. (June 2012).

[14] Greater London Authority, 2011. See citation above.

This page is intentionally blank

Thames Tideway Tunnel
Thames Water Utilities Limited

Application for Development Consent

Application Reference Number: WWO10001

Environmental Statement

Doc Ref: **6.2.03**

Volume 3: Project-wide effects assessment

Section 13: Water resources - groundwater

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

Hard copy available in

Box **17** Folder **A**
January 2013

Thames Tideway Tunnel
Creating a cleaner, healthier River Thames

This page is intentionally blank

Thames Tideway Tunnel

Environmental Statement

Volume 3: Project-wide effects assessment

Section 13: Water resources – groundwater

List of contents

Page number

List of plates

Page number

List of tables

Page number

13 Water resources – groundwater

13.1 Introduction

13.1.1 This section presents the findings of the assessment of the likely significant project-wide effects of the proposed development on groundwater.

13.1.2 The proposed development has the potential to affect groundwater quality and quantity (flows and levels) due to construction activities including:

a. dewatering of aquifer units (flows and levels)

b. mobilisation of poor quality groundwater (quality)

c. mixing of groundwater (quality)

d. use of grouts (quality)

e. physical disturbance (quality)

13.1.3 Operation of the Thames Tideway Tunnel project has the potential to affect groundwater quality and quantity through:

a. physical obstruction (flows and levels)

b. seepage from the tunnel (quality)

c. seepage into the tunnel (flows and levels)

d. reduction of pollution from storm water overflows to River Thames (quality) given the linkages between groundwater and surface water.

13.1.4 The main tunnel would pass through the London Clay in the west, through the Lambeth Group in the centre and into Thanet Sand/Chalk (lower aquifer) in the east of the proposed tunnel route. The project-wide tunnelling[i] would not affect the upper aquifer or the lower aquifer in the west. The project-wide tunnelling has the potential to affect the lower aquifer in the central and eastern areas, both in terms of groundwater quality and quantity. The significance of project-wide tunnelling construction and operational effects are considered as part of this assessment.

13.1.5 The dewatering[ii], required for the construction of some of the shafts, a number of the short connection tunnels and associated entry / exit of the tunnel boring machine (TBM), also has the potential to affect the lower aquifer in the central and eastern areas, in terms of groundwater quality and quantity. This dewatering of the lower aquifer would be concurrent at a number of sites across the project. The effect of this dewatering is

[i] Project-wide tunnelling – this term is used in the groundwater project wide assessment to describe all tunnelling taking place during the construction of the Thames Tideway Tunnel project. This includes the main tunnel and connection tunnels.

[ii] Dewatering – the control of groundwater levels, usually by abstraction, to enable construction to continue below the water table (unconfined aquifer).

considered as part of the project-wide groundwater assessment; however, the effects on the same individual receptors are assessed within the assessment area of each individual site assessment (see Vol 4-27 Section 13).

13.1.6 The assessment of groundwater presented in this section has considered the requirements of the *National Policy Statement for Waste Water* (Defra 2012)[1] Section 4.2. The physical characteristics of the groundwater environment including groundwater resources and quality are presented and the anticipated effects (including cumulative effects) on these resources and are addressed in the assessment that follows (further detail can be found in Vol 2 Section 13).

13.1.7 Plans of the proposed development as well as figures included in the assessment for the tunnel are contained in a separate volume (see Volume 3 Project-wide effects assessment figures).

13.2 Proposed development relevant to groundwater

13.2.1 The proposed development is described in Section 3 of this volume and in Section 3 of Volumes 4 to 27 Section 13. The elements of the proposed development relevant to groundwater at the project-wide scale are set out below.

Construction

13.2.2 The elements of construction for the proposed development, relevant to the consideration of groundwater, would include:

a. A main tunnel approximately 25km in length and extending from Acton Storm Tanks to Abbey Mills Pumping Station, with the following drive strategy (see Vol 3 Table 13.4.1):

   i 6.5m internal diameter (ID) main tunnel driven from Carnwath Road Riverside to Acton Storm Tanks

   ii 7.2m ID main tunnel driven from Kirtling Street to Carnwath Road Riverside

   iii 7.2m ID main tunnel driven from Kirtling Street to Chambers Wharf

   iv 7.2m ID main tunnel driven from Chambers Wharf to Abbey Mills.

b. Two long connection tunnels, with the following dimensions:

   i 5.0m ID 4.6km Greenwich connection tunnel driven from Greenwich Pumping Station to Chambers Wharf

   ii 2.6m to 3m ID 1.1km Frogmore connection tunnel driven from Dormay Street north to the main tunnel at Carnwath Road Riverside and south to King George's Park.

13.2.3 Nine short connection tunnels totalling approximately 1.2km which would be constructed in the London Clay and the Lambeth Group (see Vol 3 Table 13.4.2).

13.2.4 Twenty three main tunnel/ CSO sites (including two at Beckton Sewage Treatment Works) which would be constructed to various depths to meet the main or connection tunnels. Dewatering of the lower aquifer would be required at some of these to enable construction (see below).

13.2.5 The proposed methods of construction for these elements of the proposed development are described in Volume 1 Project Context and summarised in Vol 3 Table 13.2.1.

Vol 3 Table 13.2.1 Groundwater – assumed methods of construction

Area	site	Sprayed concrete lining (SCL)	Piled wall[iii]	Segmental shaft	Diaphragm walls[iv]	Depressurisation[v] of Lambeth Group	Dewatering of lower aquifer (external to shaft)	Dewatering of lower aquifer (internal to shaft)
West	Acton Storm Tanks	✓	✓	×	×	×	×	×
	Hammersmith Pumping Station	✓	✓	×	×	×	×	×
	Barn Elms	✓	✓	×	×	×	×	×
	Putney Bridge Foreshore	✓	✓	×	×	×	×	×
	Dormay Street	✓	✓	×	×	×	×	×
	King George's Park	✓	✓	×	×	×	×	×
	Carnwath Road Riverside	✓	✓	×	×	✓	×	×
	Falconbrook	✓	✓	×	×	×	×	×

[iii] Sheet or secant pile wall – a sub-surface structure installed to support excavation and which amongst other things helps to control inflows of shallow groundwater typically formed of intersecting concrete or overlapping shafts of concrete in the case of secant pile wall or steel in the case of a sheet pile wall..

[iv] Diaphragm wall – a sub-surface barrier installed around construction works to support the required excavation and which amongst other things helps to control inflows of groundwater typically formed of reinforced concrete. This barrier would extend down by up 8m below the base of the shaft invert, for structural reasons and to increase the length of the flow path and hence reduce the amount of groundwater inflows

[v] Depressurisation – a term used to describe dewatering or lowering of hydraulic pressures in a confined aquifer.

Area	site	Sprayed concrete lining (SCL)	Piled wall[iii]	Segmental shaft	Diaphragm walls[iv]	Depressurisation[v] of Lambeth Group	Dewatering of lower aquifer (external to shaft)	Dewatering of lower aquifer (internal to shaft)
	Pumping Station							
	Cremorne Wharf Depot	✓	✓	✗	✗	✗	✗	✗
Central	Chelsea Embankment Foreshore	✗*	✗	✓	✗	✓	✗	✗
	Kirtling Street	✗**	✗	✗	✓	✗	✓	✓***
	Heathwall Pumping Station	✓	✓	✓	✗	✓	✗****	✗****
	Albert Embankment Foreshore	✓	✓	✗	✓	✗	✓	✓
	Victoria Embankment Foreshore	✓	✓	✓	✗	✓	✗	✗
	Blackfriars Bridge Foreshore	✗	✓	✗	✓	✗	✓	✓
East	Chambers Wharf	✗	✓	✗	✓	✗	✗	✓
	King Edward	✗	✓	✗	✓	✗	✗	✓

Area	site	Sprayed concrete lining (SCL)	Piled wall[iii]	Segmental shaft	Diaphragm walls[iv]	Depressurisation[v] of Lambeth Group	Dewatering of lower aquifer (external to shaft)	Dewatering of lower aquifer (internal to shaft)
	Memorial Park Foreshore							
	Earl Pumping Station	✗	✓	✗	✓	✗	✗	✓
	Deptford Church Street	✗	✓	✗	✓	✗	✗	✓
	Greenwich Pumping Station	✗	✓	✗	✓	✗	✗	✓
	Abbey Mills Pumping Station	✓	✗	✗	✓	✗	✗	✓
	Beckton Sewage Treatment Works	✗	✓	✗	✓	✗	✗	✓

Note: Symbols ✓ applies ✗ does not apply
** Sprayed concrete lining would be required for the construction of the connection tunnel at Chelsea Embankment Foreshore.*
*** Sprayed concrete lining would be required for the construction of the chambers at the Kirtling Street site.*
**** For those sites where dewatering external to the diaphragm wall is proposed internal dewatering would also take place.*
***** Should the Lambeth Group be found to be in hydraulic connection with the lower aquifer then dewatering external to the diaphragm wall may be required.*

Code of Construction Practice

13.2.6 All works would be undertaken in accordance with the *Code of Construction Practice (CoCP)*[vi]. Relevant measures included within the *CoCP* (Part A) to ensure effects on groundwater are minimised are as follows:

a. Measures include providing bunded stores for fuel/oils held on site, polluted excavated material held at surface and the settlement of dewatering from excavations to prevent silty water from entering watercourses, surface water drains and onto roads as per *Environment Agency guidelines* (EA, 2011)[2]. The contractor would have plans and equipment in place to deal with emergency situations as well as ensuring that staff are appropriately trained.

b. A precautionary approach, involving targeted risk-based audits and checks of water quality monitoring, would be applied to licensed abstractions thought to be at risk.

c. Monitoring arrangements for dewatering permits and any permits required on change of licensing regulations would be developed in liaison with the EA (see also Vol 3 Appendix K.1 Groundwater environmental monitoring strategy).

d. At the end of construction where temporary support does not form part of the operational structure it would be removed, piped through or cut down to avoid the build-up of groundwater on the upstream side of underground structures.

Other measures during construction

13.2.7 The Thames Tideway Tunnel project has been designed to minimise environmental effects and the principles behind the construction design and methods take account of groundwater resources. These environmental design measures include:

a. The installation of shaft walls in advance of bulk excavation where required to minimise the inflow of groundwater from the upper aquifer.

b. The reduction of inflows from the lower aquifer by driving the diaphragm walls to a suitable depth to reduce inflows.

c. The use of ground treatment techniques[vii] eg, grouting or freezing to stem fissure flows if and where required.

d. The reduction of dewatering of the lower aquifer and mobilisation of poor quality groundwater by pumping internal to the diaphragm walls where feasible.

13.2.8 Dewatering of the lower aquifer would be necessary during the construction of the shafts, connection tunnels and associated entry / exit of

---

[vi] The *Code of Construction Practice* (CoCP) is provided in Vol 1 Appendix A. It contains general requirements (Part A), and site specific requirements for this site (Part B).

[vii] Ground treatment – stabilisation of soils/rocks by injection of grouts and or freezing techniques.

the TBM. This would involve drilling wells into the lower aquifer and pumping to lower the pressure. These wells would be drilled external to the diaphragm walls or secant piling, with the exception of where the transmissivity[viii] of the Chalk is high (1,200 to 3,000m^2/d) or where groundwater quality exceedances were identified in the Chalk. The selection of closed face tunnelling (utilising either Earth Pressure Balance or Slurry tunnelling techniques) eliminates the need for dewatering along the tunnel route. A summary of the dewatering method at each of the proposed sites is given in Vol 3 Table 13.5.1.

13.2.9 Depressurisation of the Lambeth Group would be necessary during the construction of shafts, connection tunnels and associated entry/ exit of the TBM, where construction does not take place within or close to the top of the lower aquifer. This would involve drilling wells into the Lambeth Group and pumping to lower the pressure. These wells would be drilled external to the diaphragm walls or scent piling. The Lambeth Group is not considered an aquifer and therefore the impacts of depressurisation on groundwater levels and quality are not assessed in this volume or in the individual site assessments.

13.2.10 Ground treatment, including fissure grouting[ix], below the base of the shaft or the toe of the diaphragm walls would be required in the Upnor Formation, Thanet Sand and Chalk (lower aquifer) for shaft construction and on either side of the shaft to facilitate TBM break in/ break out. A summary of the ground treatment anticipated at each proposed site is given in Vol 3 Table 13.5.4.

13.2.11 Void grouting would also be required to fill the void between the tunnel rings and the ground, and would be injected as the TBM advances. The use of any grouting products would be approved by the EA. The application would prevent the loss of hazardous substances and would control loss of non-hazardous substances to groundwater.

Operation

13.2.12 The operational infrastructure is summarised briefly in para. 13.2.2 and further details are provided in Vol 1 Section 2.

13.2.13 The design of the combined sewer overflow (CSO) drop shafts, the main tunnel shafts and tunnels includes a lining, which as well as providing structural integrity, would minimise the possibility of groundwater infiltration into the drop shaft when empty.

13.2.14 On the occasions when the shafts and tunnel would be full (and when there would be an increased potential for seepage out), the lining provides additional hydraulic security to ensure sewage would not be able to exfiltrate[x] from the shafts and tunnel.

[ix] Grouting – a thin, coarse mortar poured into various narrow cavities, such as rock fissures, to fill them and consolidate the adjoining objects into a solid mass.

[x] Exfiltrate – the movement of a substance from within a contained structure, the opposite of infiltrate.

13.2.15 A groundwater environmental monitoring strategy is one of the project's environmental design measures (see Vol 3 Appendix K.1). This covers groundwater levels and groundwater quality and outlines the future monitoring and actions in the event of trigger levels being exceeded.

13.3 Assessment methodology

13.3.1 The methodology for preparing the project-wide effects assessment is described in Volume 2 Environmental assessment methodology Section 13. Engagement and methodological assumptions and the limitations of specific relevance to the project-wide assessment are detailed below.

13.3.2 The overall peak in construction activities across all sites between 2016 (Year 1 of construction) and 2022 (Year 7 of construction), is identified to be 2017 (Year 2 of construction); therefore this year is the assessment year applied to the project-wide construction assessment. The assessment year applied to the project-wide operational assessment is 2023 (Year 1 of the operational phase).

13.3.3 The lower aquifer and licensed abstraction sources within this aquifer are considered to be the receptors capable of experiencing project-wide effects. The effects of dewatering on licensed abstractions are also considered in the site specific assessments where licensed abstractions are within the assessment area of the site.

13.3.4 The effects of dewatering are considered in combination using the principles of superposition[xi], appropriate to the ubiquitous nature of groundwater in the subsurface, and therefore are considered project-wide effects.

13.3.5 Where dewatering external to diaphragm walls is proposed at sites, the effects of mobilising poor quality groundwater on the lower aquifer and on nearby licensed abstractions are assessed and the results are reported in both this volume and the site-specific sections (ie, Kirtling Street Vol 14 Section 13, Albert Embankment Foreshore Vol 16 Section 13 and Blackfriars Bridge Foreshore Vol 18 Section 13).

Engagement

13.3.6 Vol 2 documents the overall engagement which has been undertaken in preparing the *Environmental Statement*. Specific comments relevant to the project-wide assessment of effects on groundwater resources are presented in Vol 3 Table 13.3.1.

Vol 3 Table 13.3.1 Groundwater – stakeholder engagement

Organisation	Date	Comment	Response
Environment Agency (EA)	April 2011	Elevated salinity concentrations to east of main tunnel route due	Addressed in Section 13.5

[xi] The superposition principle states that the net response at a given place and time caused by two or more stimuli is the sum of the responses which would have been caused by each stimulus individually.

Organisation	Date	Comment	Response
		to abstractions	
		Information on the risks and mitigation for significant pathway, migration or mixing	Addressed in Section 13.5
		Check significance of effects as a result of physical disturbance within Chalk	Addressed in Section 13.5
		Data used to define seepage inflow/ outflow head difference	Addressed in Section 13.6
		Worst case effects & inflow/ outflow when groundwater levels are the same as those in the tunnel	Addressed in Sections 13.6 and 13.8
		Check effects during operation	Addressed in Section 13.6
National Grid	Feb. 2012	Potential cumulative effect of National Grid cable tunnel under construction within close proximity to proposed main tunnel route of the Thames Tideway Tunnel project.	Two locations in Wandsworth, one near King George's Park and a second under the River Thames at the mouth of River Wandle. These are addressed in the individual site assessments (Vol 9 Section 13 and Vol 8 Section 13).

Note: No comments on groundwater issues at the scoping stage were received from London Borough (LB) of Southwark LB of Hounslow, City of London, LB of Lewisham, LB of Newham, LB of Ealing, RB of Greenwich, LB of Bexley and LB of Kingston upon Thames. Site-specific comments on groundwater issues were received from LB of Wandsworth, LB of Tower Hamlets, RB of Kensington and Chelsea and LB of Lambeth, but no project-wide comments were received

Baseline

13.3.7 The baseline methodology follows the methodology described in Vol 2 Section 13.

13.3.8 The baseline and the assessment of potential effects have considered receptors within 1km of the CSO drop shafts and main sites and of the tunnels during both construction and operation.

13.3.9 This project-wide effects assessment takes account of receptors which are located within 1km of the sites, which are not affected by the construction methods at the drop/main tunnel sites themselves but which are impacted by dewatering of the lower aquifer (each of the individual site assessments describes the likely significant effects of the project on receptors within a kilometre of the site these can be found in Vols 4 to 27 Section 13). This section also takes account of receptors which are located beyond 1km of the sites and the tunnels.

Construction

13.3.10 The assessment methodology for the construction phase follows that described in Vol 2 Section 13.

13.3.11 The overall peak year in construction activities across all sites would be 2017 and this is the assessment year applied to the construction assessment. This is when volumes of dewatering would be at their greatest. The baseline is not anticipated to vary substantially between 2011 and the assessment year and so baseline data from 2011 have formed the base case for the construction assessment. A number of proposed developments which are likely to be complete and operational before commencement of construction have formed part of the construction base case.

13.3.12 The local-scale developments are considered as part of the individual shaft assessment base case and included in the individual shaft assessment. The London-wide developments which are considered as part of the project-wide assessment base case and are included in the project-wide cumulative effects assessment are identified in Vol 3 Table 13.3.2.

Vol 3 Table 13.3.2 Groundwater – construction base case and cumulative assessment developments (2017)

Development	Component or receptor relevant to groundwater	Construction base case	Cumulative effect assessment
Thameslink	Tunnels* Permitted dewatering ** for construction until 2018	✓	✗
Crossrail	Tunnels* Permitted dewatering ** for construction until 2017	✓	✓
Northern Line Extension	Tunnels*	✓	✓

Note: Symbols ✓ applies ✗ does not apply
** Relevant to upper and lower aquifers*
*** Relevant to lower aquifer only*

Operation

13.3.13 The assessment methodology for the operational phase follows that described in Vol 2 Section 13.

13.3.14 The assessment year applied to the operational assessment is Year 1 of operation. The baseline is not anticipated to vary significantly before the start of the operational phase in 2023; and therefore, the baseline data from 2011 has formed the base case for the operational assessment. In addition, information on proposed developments likely to have been completed before commencement of operation of the Thames Tideway Tunnel project have formed the operational base case.

13.3.15 The local-scale developments are considered as part of the individual shaft assessment base case and those are included in the individual shaft cumulative effects assessment. The London-wide developments which are considered as part of the project-wide shaft assessment base case and are included in the project-wide assessment are identified in Vol 3 Table 13.3.3.

Vol 3 Table 13.3.3 Groundwater – operational base case and cumulative assessment (2023)

Development	Component or receptor relevant to groundwater	Operational base case	Cumulative effect assessment
Thameslink	Tunnels* Permitted dewatering** for construction until 2018	✓	✗
Crossrail	Tunnels* Permitted dewatering ** for construction until 2017	✓	✗
Northern Line Extension	Tunnels*	✓	✗

Note: Symbols ✓ applies ✗ does not apply
** Relevant to upper and lower aquifers*
*** Relevant to lower aquifer only*

Assumptions and limitations

Assumptions

13.3.16 The assessment of dewatering in Section 13.5 is based on a quantitative assessment of dewatering on the lower aquifer using the best available hydraulic property information. A distributed groundwater model has been developed for the purpose of this quantitative assessment and used the following hydraulic properties for the Chalk: a distribution of transmissivity[xii] ranging from $10m^2/d$ to $2000m^2/d$ (EA and ESI, 2010)[3] and a storativity[xiii] value of approximately 1×10^{-4} (see Vol 3 Appendix K.2 Supporting modelling report).

[xii] Transmissivity - the ability of rock to transmit water which is a function of its permeability and thickness

[xiii] Storativity – the volume of water released for a unit change in water level (in a confined aquifer)

13.3.17 The assessment of dewatering in Section 13.5 is based on the principle of superposition, in that the effects of lowering groundwater levels are inherently project-wide by virtue of the extent of the upper and lower aquifers and of the effects of interference between zones of drawdown.

13.3.18 This assessment has assumed that a lining within the drop/main shafts and the tunnels would have a rate of seepage of $1l/m^2/d$ (Vol 2 Appendix K.3). This is a conservative value used for the purposes of the assessment.

Limitations

13.3.19 No site-specific pumping tests have yet been undertaken as part of the ground investigations. In the absence of project-specific hydrogeological data, published sources of hydrogeological information have been used in this assessment.

13.3.20 There have been limited water level data available for this assessment, with monitoring data typically available only from one borehole (or monitoring horizon) within the upper and lower aquifers at each drop shaft site. This means that hydraulic gradients[xiv] could only be estimated across the sites. In addition, the range of hydrological conditions experienced during the monitoring period (2010-2012) has not included a prolonged wet winter period when exceptionally high groundwater levels might be expected to occur.

13.3.21 There has been limited groundwater quality data available for this assessment.

13.3.22 Despite the limitations identified above, the assessment which uses the best available information is considered robust.

13.4 Baseline conditions

13.4.1 The following section sets out the baseline conditions for groundwater across the tunnel route. Future baseline conditions (base case) are also described.

Current baseline

Geology

13.4.2 The route of the main tunnel would pass from west to east through a sequence of sedimentary strata from the London Clay Formation for approximately 12,000m then through the Lambeth Group (6,400m), Thanet Sands Formation (600m) and finally into the Chalk Group (6,100m). This sequence is shown in Vol 3 Table 13.4.1.

13.4.3 The drive lengths, geology and hydrogeology through each of the London Boroughs are summarised for the main tunnel and short connection tunnels in Vol 3 Table 13.4.1 and for short connection tunnels in Vol 3 Table 13.4.2.

[xiv] Hydraulic gradient – the slope of the water table which drives groundwater movement

13.4.4 Of the twenty three shafts, nine shafts would extend down into the London Clay Formation, eight into the Lambeth Group and six into the Seaford Chalk. The geology and hydrogeology at these sites are summarised in Vol 3 Table 13.4.3.

Vol 3 Table 13.4.1 Groundwater – geology and hydrogeology of main tunnel and short connection tunnel sections

Area	Tunnel section	London Borough	Tunnel chainage (m)		Tunnel length (m)	Tunnel diameter (ID, m)	Formation	Hydro-geology
West	Acton Storm Tanks to Hammersmith Pumping Station	Ealing/Hounslow / Hammersmith & Fulham	0	3,045	3,045	6.5	London Clay	Aquiclude [xv]
	Hammersmith Pumping Station to Barn Elms	Hammersmith & Fulham / Richmond upon Thames	3,045	4,740	1,695			
	Barn Elms to Putney Embankment Foreshore	Richmond upon Thames / Hammersmith & Fulham/ Wandsworth	4,740	5,457	717			
	Putney Embankment Foreshore to Carnwath Road Riverside	Hammersmith & Fulham / Wandsworth	5,457	6,947	1,490			
	Frogmore Connection Tunnel - Carnwath Road Riverside to King George's Park	Hammersmith & Fulham / Wandsworth	-	6,840	1,100	2.6		
	Carnwath Road Riverside to Falconbrook	Hammersmith & Fulham/ Wandsworth	6,947	8,030	1,083	7.2		

[xv] *Aquiclude – a hydrogeological unit which, although porous and capable of storing water, does not transmit it at rates sufficient to furnish an appreciable supply for a well or spring (USGS, 1989).*

Area	Tunnel section	London Borough	Tunnel chainage (m)		Tunnel length (m)	Tunnel diameter (ID, m)	Formation	Hydro-geology
	Falconbrook Pumping Station to Cremorne Wharf Depot	Wandsworth/ Hammersmith & Fulham/ RB Kensington & Chelsea	8,030	9,177	1,147			
	Cremorne Wharf Depot to Chelsea Embankment Foreshore	RB Kensington & Chelsea	9,177	10,959	1,782			
Central	Chelsea Embankment Foreshore to Kirtling Street	RB Kensington & Chelsea/ Wandsworth	10,959	11,943	11,943		Lambeth Group* USB UMB Sand Channel LtB/LSB LMB UPN(Gv) UPN	Aquitard[xvi] / aquifers
	Kirtling Street to Heathwall Pumping Station	Wandsworth	11,943	12,310	12,310	7.2		
	Heathwall Pumping Station to Albert Embankment Foreshore	Wandsworth/ Lambeth / City of Westminster	12,310	13,246	13,246			
	Albert Embankment Foreshore to Victoria Embankment Foreshore	Lambeth / City of Westminster	13,246	15,160	15,160			
	Victoria Embankment Foreshore to Blackfriars Bridge Foreshore	City of Westminster / City of London	15,160	16,387	16,387			

[xvi] *Aquitard – a poorly-permeable geological formation that does not yield water freely, but may still transmit significant quantities of water to or from adjacent aquifers (EA, 2012).*

Area	Tunnel section	London Borough	Tunnel chainage (m)		Tunnel length (m)	Tunnel diameter (ID, m)	Formation	Hydro-geology
	Blackfriars Bridge Foreshore to Chambers Wharf	City of London/ Southwark	16,387	19,562	19,562		Thanet Sand	Lower aquifer
East	Chambers Wharf to King Edward Memorial Park	Southwark/ Tower Hamlets	19,562	21,176	21,176		Seaford Chalk	
	King Edward Memorial Park to Abbey Mills Pumping Station	Tower Hamlets/ Newham	21,176	25,087	25,087			
	Greenwich connection tunnel - Chambers Wharf to Greenwich Pumping Station	Southwark/ Lewisham/ RB Greenwich	-	19,510	2,240	5.0		

*Note: * USB–Upper Shelly Beds; UMB–Upper Mottled Beds; LtB–Laminated Beds; LSB-Lower Shelly Beds; LMB-Lower Mottled Beds; UPN (Gv)-Upnor Formation(Gravel); UPN-Upnor Formation*

Vol 3 Table 13.4.2 Groundwater – geology and hydrogeology of short connection tunnel sections

Area	Tunnel section	London Borough	Main tunnel chainage (m)	Tunnel length (m)**	Tunnel diameter (ID, m)	Formation	Hydrogeology
West	Hammersmith connection tunnel	Hammersmith & Fulham	3,045	301	4.0	London Clay	Aquiclude
	West Putney connection tunnel	Richmond upon Thames	4,740	220	2.2		
	Putney Bridge connection tunnel	Wandsworth	5,457	54	2.2		
	Falconbrook connection tunnel	Wandsworth	8,030	257	3.2		
	Cremorne Wharf Depot to main tunnel	RB Kensington & Chelsea	9,177	188	3.0		
Central	Chelsea Embankment Foreshore to main tunnel	RB Kensington & Chelsea	10,959	66	4.0	Lambeth Group* USB UMB Sand Channel LtB/LSB LMB UPN(Gv) UPN	Aquitard/ aquifers
	Heathwall Pumping Station to Kirtling Street	Wandsworth	12,310	56	4.0		
	Albert Embankment Foreshore to main tunnel	Lambeth	13,246	24	3.0		
	Victoria Embankment Foreshore to main tunnel	City of Westminster	15,160	30	3.0		Lower aquifer

*Note: * USB–Upper Shelly Beds; UMB–Upper Mottled Beds; LtB–Laminated Beds; LSB-Lower Shelly Beds; LMB-Lower Mottled Beds; UPN (Gv)-Upnor Formation(Gravel); UPN-Upnor Formation** Connection tunnel length is measured from the centre of the main tunnel to the centre of the main shaft and is rounded to the nearest meter*

Vol 3 Table 13.4.3 Groundwater – geology and hydrogeology of sites

Area	site	London Borough	Main tunnel chainage (m)	Shaft depth* (m)	Shaft diameter (ID, m)	Formation at base slab	Hydrogeology
West	Acton Storm Tanks	Ealing	0.000	30.8	15.0	London Clay	Aquiclude
	Hammersmith Pumping Station	Hammersmith & Fulham	3,045	32.6	11.0		
	Barn Elms	Richmond upon Thames	4,740	33.8	6.0		
	Putney Embankment Foreshore	Wandsworth	5,457	36.2	6.0		
	Carnwath Road Riverside	Hammersmith & Fulham	6,947	42.3	25.0		
	Dormay Street	Wandsworth	-	23.6	12.0		
	King George's Park	Wandsworth	-	20.4	9.0		
	Falconbrook Pumping Station	Wandsworth	8,030	40.1	9.0		
	Cremorne Wharf Depot	RB Kensington & Chelsea	9,177	42.1	8.0		
Central	Chelsea Embankment Foreshore	RB Kensington & Chelsea	10,959	45.5	12.0	Lambeth Group USB	Aquitard/ aquifers
	Kirtling Street	Wandsworth	11,943	47.6	30.0	Lambeth Group UPN	
	Heathwall Pumping Station	Wandsworth	12,310	46.3	16.0	Lambeth Group LMB	

Area	site	London Borough	Main tunnel chainage (m)	Shaft depth* (m)	Shaft diameter (ID, m)	Formation at base slab	Hydrogeology
	Albert Embankment Foreshore	Lambeth	13,246	47.1	16.0	Lambeth Group UPN	
	Victoria Embankment Foreshore	City of Westminster	15,160	49.5	16.0	Lambeth Group LMB	Lower aquifer
	Blackfriars Bridge Foreshore	City of London	16,387	53.3	24.0	Thanet Sand	
Eastern	Chambers Wharf	Southwark	19,562	57.3	25.0	Seaford Chalk	
	King Edward Memorial Park	Tower Hamlets	21,176	60.3	20.0		
	Earl Pumping Station	Southwark	-	49.3	17.0		
	Deptford Church Street	Lewisham	-	45.9	17.0		
	Greenwich Pumping Station	RB Greenwich	-	46.6	17.0		
	Abbey Mills Pumping Station	Newham	25,087	66.8	20.0		
	Beckton Sewage Treatment Works	Newham	-	32.0	9.0	Lambeth Group UPN*	
				30.0	7.0		

*Note: * Excludes base slab*
USB–Upper Shelly Beds; UMB–Upper Mottled Beds; LtB–Laminated Beds; LSB-Lower Shelly Beds; LMB-Lower Mottled Beds; UPN (Gv)-Upnor Formation(Gravel); UPN-Upnor Formation

Hydrogeology

13.4.5 The Chalk is the major aquifer of the London Basin and is confined over much of the area by the Tertiary formations (the Lambeth Group and Thanet Sands) and superficial deposits (Alluvium and River Terrace Deposits). The Chalk is classified by the EA as a principal aquifer [xvii]. The confined[xviii] Chalk has an area of approximately 3,700km^2 within the centre of the London Basin (EA, 2006)[4].

13.4.6 The most permeable superficial deposits, the River Terrace Deposits, are referred to as the upper aquifer and are classified by the EA as a secondary A aquifer[xix]. The Alluvium, overlying the River Terrace Deposits, may act as confining layer for the upper aquifer at certain locations. At other locations, the Alluvium may be in hydraulic continuity with the upper aquifer.

13.4.7 The upper and lower aquifers are generally hydraulically separated by the London Clay Formation. The London Clay Formation is considered to act as an aquiclude, in which any groundwater present is likely to consist of localised seepages and/or minor flows, with the exception of unit A3ii (upper unit of the London Clay) which is regarded as the most porous section of this formation. The London Clay Formation is absent or less than 1m thick at the King Edward Memorial Park, Earl Pumping Station, Deptford Church Street and Greenwich Pumping Station sites and therefore in these locations, depending on local conditions, the upper and lower aquifers may be in hydraulic continuity.

13.4.8 The Harwich Formation is present across much of the assessment area and is considered to form a minor aquifer unit where it is isolated from the lower aquifer by the Lambeth Group.

13.4.9 Within the Lambeth Group, several confined groundwater bodies are expected to be encountered. Groundwater is expected to be present through the Upper Shelly Beds and Upper Mottled Beds (potentially small inflows) and under high pressure within the Laminated Beds (formerly part of the Woolwich Formation).

13.4.10 The Thanet Sands and the Upnor Beds (lower unit of the Lambeth Group) are known as the ‘Basal Sands’ and are in hydraulic continuity with the Chalk aquifer beneath London. The Basal Sands are classified by the EA as a secondary aquifer. The Basal Sands and the Chalk together are referred to as the lower aquifer, which is classified as a principal aquifer on account of the high yielding properties of the Chalk.

[xvii] Principal aquifer – a geological stratum that exhibits high inter-granular and /or fracture permeability (was previously referred to as a major aquifer)

[xviii] Confined - a term used to describe an aquifer in which water is held under pressure, such that groundwater in a borehole penetrating a confined aquifer would rise to a level above the top of the aquifer

[xix] Secondary A aquifer – permeable layers capable of supporting water supplies at a local rather than strategic scale, and in some cases forming an important source of base flow to rivers. These are generally aquifers formerly classified as minor aquifers (EA, 2012).

13.4.11 The EA have produced a groundwater contour map of the Chalk piezometric[xx] levels for January 2011 (see Vol 3 Figure K.1.1 in separate volume of figures). The map shows the regional direction of groundwater flow within the London Basin to be towards a point of low piezometric levels within central London. However, the groundwater gradient may be affected locally by abstraction, particularly during peak demand periods associated with major licences.

13.4.12 There are limited monitoring boreholes within the upper aquifer and at most sites it has not possible to accurately determine the direction of groundwater flow at these depths; however it is likely to be local and towards the River Thames due to surrounding topography.

Licensed abstractions

13.4.13 Details of abstractions and protected rights relevant to the sites and tunnel route are identified as part of this assessment. This includes all abstractions located within 1km of the proposed sites and the proposed tunnel route.

13.4.14 There is one EA licensed abstraction from the upper aquifer located within 1km of the proposed sites and the tunnel route (28/39/39/0225). This licensed abstraction abstracts from the River Terrace Deposits and is included in Vol 3 Table 13.4.4 in the central area under industrial, commercial and public service purposes.

13.4.15 There are 40 EA licensed abstractions from the lower aquifer either located within 1km of the proposed sites or the tunnel route. Where abstractions are identified to be of particular importance and are beyond a kilometre from the tunnel they have also been considered. These are distributed along the length of the tunnel and ensure a comprehensive coverage of all the potential unknown receptors which may be affected. These licensed abstractions are summarised in Vol 3 Table 13.4.4.

Vol 3 Table 13.4.4 Groundwater – EA licensed abstractions

Area	Licence purpose	No. of licences
Central	Drinking water supply	11
	GSHP (heat pump or cooling)	12
	Industrial, commercial & public service (process water or irrigation)	5
Eastern	Drinking water supply	5
	GSHP (cooling)	3
	Industrial, commercial & public service (amenity top up water or horticultural)	4

[xx] Piezometric head or level – the level or pressure head to which confined groundwater would rise to in a piezometer if it is open to the atmosphere.

13.4.16 There are three unlicensed abstractions from the Chalk aquifer located within 1km of the sites and tunnel route, based on information provided by the London Boroughs. One of these unlicensed sources is used for drinking water supply purposes; the purpose of the remaining two is unknown.

Groundwater source protection zones

13.4.17 The EA defines Source Protection Zones[xxi] (SPZ) around all major public water supply abstractions sources and large licensed private abstractions. SPZ's are split into three zones: an SPZ 1 defined as a 50 day travel time to a source; an SPZ 2 defined as a 400 day travel time to a source; and an SPZ 3 represents the total catchment zone of a source.

13.4.18 The proposed sites are within, and the tunnel route crosses, two SPZ's, including the combined SPZ for two Thames Water Utilities' sources and an SPZ for a third party private abstraction (see Vol 3 Figure K.1.1 in separate volume of figures).

Environmental designations

13.4.19 The Barn Elms Site of Special Scientific Interest (SSSI) is located 140m to the north of a proposed site (Barn Elms) and from the main tunnel route.

13.4.20 The London Basin, including the River Thames, is designated as a Natural Landscape Area (Natural England, 2012)[5] and a Site of metropolitan importance for nature conservation. However, due to the depth of the tunnel, interaction between the tunnel construction and operation and the river is not anticipated. Furthermore as no dewatering of the upper aquifer is expected to be required at the sites. Interaction with near surface aquatic environments is also not anticipated.

13.4.21 There are no other environmental designations directly relevant to groundwater in close proximity to the tunnel route.

Groundwater quality and land quality

13.4.22 The baseline groundwater quality data have been sourced from the ground investigation and monitoring works undertaken as part of the Thames Tideway Tunnel project and compared to The Water Supply (Water Quality) Regulations, 2000 and relevant Environmental Quality Standards (EQS).

13.4.23 In addition, historical land use mapping, reviewed as part of the land quality assessment, identified several potentially contaminative land uses at or nearby the sites (Vol 4 to Vol 27 Section 8.4). Land quality may impact on groundwater quality through the creation or promotion of preferential pathways for groundwater quality exceedances during construction of the proposed development.

[xxi] Source Protection Zone – which are designed to safeguard groundwater resources from potentially polluting activities.

Upper aquifer

13.4.24 Widespread existing groundwater quality exceedances have been identified within the River Terrace Deposits (or upper aquifer). These exceedances of the relevant standards generally relate to ammonia, nitrate, heavy metals, pesticides, hydrocarbons (including polycyclic aromatic hydrocarbon (PAHs) and turbidity and are summarised in Vol 3 Table 13.4.5. PAHs may be formed during a range of human activities, including incomplete combustion of carbon-based fuels and other industrial processes (EA, 2010)[6]. In addition, PAHs are considered to be Priority Hazardous Substances under the Water Framework Directive (Commission of the European Communities, 2009)[7].

13.4.25 The geographical distribution of sites with groundwater quality exceedances in the upper aquifer is mainly within the eastern part of Thames Tideway Tunnel project route, where heavy industries have historically been found, but also at a small number of central and western sites. The number of sites with known (based on data gathered) or suspected groundwater quality exceedances (based on reviews of historical land use – see para.13.4.26) is thirteen (out of a total number of 22 sites with available baseline groundwater quality data). This level of exceedance aligns with information gathered by the EA in its baseline surveys for the River Thames Gravels (upper aquifer) (EA, 2006)[8]. In this report, it states that “The impact of urban development is seen, particularly in the Thames Valley area, through increased occurrence of copper and chromium, as well as some industrial solvents”.

Vol 3 Table 13.4.5 Groundwater – groundwater quality exceedances in upper aquifer

Area	site	Brackish conditions	Turbidity	Heavy metals	Hydro-carbons	Pesticides	Ammonia/ Nitrate
Western	Acton Storm Tanks	×	✓	✓	×	×	×
	Hammersmith Pumping Station	×	×	×	✓	×	✓ (Nitrate)
	Barn Elms	×	×	×	×	×	✓ (Nitrate)
	Putney Embankment Foreshore	×	×	×	×	×	✓ (Nitrate)
	Dormay Street	×	×	✓	✓	✓	×
	King George's Park	×	×	✓	✓	✓	×
	Carnwath Road Riverside	-	-	-	-	-	-
	Falconbrook Pumping Station	×	✓	✓	✓	✓	✓
Central	Cremorne Wharf Depot	×	×	×	✓	×	×
	Chelsea Embankment Foreshore	✓	✓	✓	✓	✓	✓

Area	site	Brackish conditions	Turbidity	Heavy metals	Hydro-carbons	Pesticides	Ammonia/ Nitrate
	Kirtling Street	✓	✓	✓	×	✓	✓
	Heathwall Pumping Station	✓	✓	✓	×	✓	✓
	Albert Embankment Foreshore	×	×	×	×	×	✓ (Nitrate)
	Victoria Embankment Foreshore	×	×	×	×	×	×
	Blackfriars Bridge Foreshore	×	×	×	×	×	×
Eastern	Chambers Wharf	×	×	×	×	×	×
	King Edward Memorial Park	×	✓	✓	×	×	✓ (Nitrate)
	Earl Pumping Station	✓	×	✓	✓	✓	×
	Deptford Church Street	✓	×	×	×	×	×
	Greenwich Pumping Station	✓	×	×	×	×	×
	Abbey Mills Pumping Station	-	-	-	-	-	-
	Beckton Treatment Works	✓	×	×	✓	×	×

✓Present ×Absent – No available water quality data

Lower aquifer

13.4.26 Several ‘hotspots’ of groundwater quality exceedances have been identified within the Thanet Sands and the Chalk (lower aquifer), around the central and eastern sites. These exceedances are spatially variable and indicative of poor baseline groundwater quality near the sites and the tunnel route. The groundwater quality exceedances with respect to ammonia, heavy metals, organics (hydrocarbons, including PAH’s), pesticides and turbidity within the lower aquifer identified within 1km of the central and eastern sites and tunnelling sections, are summarised in Vol 3 Table 13.4.6.

13.4.27 Approximately ten sites (out of total of 14 central and eastern sites) are known to be or expected to have exceedances within the lower aquifer. This distribution of exceedances aligns with information gathered by the EA in its baseline surveys for the Chalk (lower aquifer) (EA, 2006). In this report it states that “Of the organic chemicals detected, industrial solvents, herbicides and phenol have been found frequently (in up to 45% of samples) but usually at low concentrations”.

13.4.28 In addition, elevated baseline levels of salinity are present within the upper and lower aquifers along the eastern part of the main tunnel route and around the eastern sites. The occurrence of brackish conditions is to be expected given the close proximity of the tunnel route to the tidal Thames. These conditions are likely to be exacerbated by large-scale abstractions within the Chalk if these draw brackish water into the aquifer.

Vol 3 Table 13.4.6 Groundwater – groundwater quality exceedances in lower aquifer

Area	site	Brackish conditions	Turbidity	Heavy metals	Hydro-carbons	Pesticides	Ammonia
Central	Cremorne Wharf Depot	-	-	-	-	-	-
	Chelsea Embankment Foreshore	×	×	×	×	×	-
	Kirtling Street	×	✓	✓	✓	×	✓
	Heathwall Pumping Station	×	✓	✓	✓	×	✓
	Albert Embankment Foreshore	×	✓	✓	✓	×	✓
	Victoria Embankment Foreshore	×	×	×	×	×	-
	Blackfriars Bridge Foreshore	×	×	×	×	×	-
Eastern	Chambers Wharf	✓	✓	✓	×	✓	✓
	King Edward Memorial Park	✓	✓	✓	✓	×	✓
	Earl Pumping Station	✓	×	✓	✓	✓	✓

Area	site	Brackish conditions	Turbidity	Heavy metals	Hydro-carbons	Pesticides	Ammonia
	Deptford Church Street	✓	✓	✓	✓	✓	-
	Greenwich Pumping Station	✓	✓	✓	✓	✓	-
	Abbey Mills Pumping Station	✓	×	✓	✓	×	✓
	Beckton Treatment Works	✓	-	×	✓	-	✓

Note: ✓ Present × Absent – No available water quality data

Groundwater flood risk

13.4.29 There have been a number of incidents of groundwater flooding recorded within the vicinity of the sites and the tunnel route, based on information from the respective London Borough's Strategic Flood Risk Assessments. Because of the depth of the tunnel, no interaction is anticipated between the tunnel construction and operation and groundwater flooding at the project-wide scale. Groundwater flood-risk is therefore assessed only in relation to works at the individual sites (see respective site assessments, Vol 4-27 Section 15) and is not addressed further in this volume.

Groundwater/ surface water interaction

13.4.30 Within the London Basin, groundwater is known to discharge to surface water bodies in areas of Chalk outcrop such as in the River Thames area from Greenwich to Woolwich (in east London) and in areas of thinly deposited Lambeth Group such as in Hackney and the Lee Valley. Groundwater from southeast London interacts with the River Thames from Greenwich to Woolwich and there is potential for saline tidal river water to enter the aquifer in this area (EA, 2010)[9].

13.4.31 As noted above, the baseline groundwater quality data shows exceedances of chloride, sodium and electrical conductivity at all of the eastern sites, which is indicative of brackish conditions due to saline intrusion from the tidal Thames. In addition, exceedances of ammonia are widespread across the central and eastern areas, which is indicative of contamination by wastewater. While likely to be exacerbated by large-scale abstraction within the London area, these conditions indicate the potential for saline tidal river water and possibly ammonia-contaminated river water to enter the lower aquifer in this area.

Groundwater status

13.4.32 The EC Water Framework Directive (WFD) requires the status of groundwater management units (groundwater bodies) within each river basin to be determined as 'good' or 'poor' by 2015. There are two separate classifications for groundwater bodies; chemical status and quantitative status.

13.4.33 The *Thames River Basin Management Plan (*RBMP) (EA, 2009)[10] shows no groundwater body designation for the lower aquifer over the western and central areas of the tunnel route; therefore no baseline assessment of quantitative or chemical status is available.

13.4.34 The eastern area of the tunnel route is within the designated Greenwich Chalk and Tertiaries groundwater body (consisting of the Lambeth Group, Thanet Sands, Blackheath Formation and Chalk Formation). In 2009, the quantitative status of the Greenwich Chalk and Tertiaries groundwater body was assessed to be poor (good for groundwater dependent terrestrial ecosystems and resource balance and poor for impact on surface waters and saline or other intrusions). In 2009, the chemical status was also assessed to be poor (good for general chemical assessment, groundwater dependent terrestrial ecosystems and impact on surface water chemical/ ecological status and poor for saline or other intrusions and drinking water protected areas). The current status highlights the impact of saline intrusion on the lower aquifer in this area.

13.4.35 The predicted quantitative and chemical quality is poor for 2015 due to treatment or improvement being disproportionately expensive or technically infeasible.

Groundwater receptors

13.4.36 Groundwater receptors which could be affected during construction or operation of the sites, the main tunnel and the connection tunnels are shown in Vol 3 Table 13.4.7.

Vol 3 Table 13.4.7 Groundwater – receptors

Receptor	Construction			Operation			Comment
	W	C	E	W	C	E	
Groundwater resources – upper aquifer	×	×	×	×	×	×	Penetrated by shafts, interception chambers & culverts; however no dewatering as sealed out by sheet or secant piling, jacked caissons or diaphragm walls.
Groundwater resources - lower aquifer	×	✓	✓	×	✓	✓	Shafts and tunnels constructed through London Clay Formation in western area, Lambeth Group in central area and through Thanet Sands and into Chalk in eastern area.
Licensed abstractions – upper aquifer	×	×	×	×	×	×	One licensed abstraction identified within 1km of proposed development but not impacted as no dewatering.
Licensed abstractions – lower aquifer	×	✓	✓	×	✓	✓	Forty licensed abstractions identified within 1km of proposed development and two SPZ's (zones 1-3) traversed
Unlicensed abstractions	×	✓	✓	×	✓	✓	Three unlicensed abstractions identified within 1km of proposed development.

Note: ✓ Present × Absent
W – West, C – Central, E – East

Receptor sensitivity

13.4.37 The upper aquifer is classified by the EA as a secondary A aquifer and is allocated a medium value with regard to both quantity and quality on a project-wide basis.

13.4.38 The lower aquifer is a principal aquifer (the Chalk) and so is classed as being of high value with regard to quantity. The lower aquifer is characterised by brackish conditions in places (see Vol 3 Table 13.4.5). In some cases, the EA considers these conditions impossible or uneconomic to remediate to levels below the natural background. However, the Chalk is used as a source of major public water supply within this eastern area (for example, Thames Water's Deptford source located near Greenwich), suggesting that these conditions are localised. Therefore the lower aquifer is also allocated a high value with regard to quality on a project-wide basis.

13.4.39 The sensitivity of individual abstraction licences has been assessed depending on their use, for example, a higher value is given to sources used for drinking water (both public and private supplies) than for industrial purposes, which in turn are given a higher value than for amenity purposes. Also larger public water supply abstractions are given a higher value than generally smaller domestic supplies.

13.4.40 A summary of the value and sensitivity of relevant receptors is given in Vol 3 Table 13.4.8.

Vol 3 Table 13.4.8 Groundwater – receptor value/ sensitivity

Receptor	Value/sensitivity
Groundwater quality	
Upper aquifer	Medium value; secondary A aquifer.
Lower aquifer	High value; principal aquifer.
Groundwater quantity (resources)	
Upper aquifer	Medium value; secondary A aquifer.
Lower aquifer	High value; principal aquifer.
Licensed River Terrace Deposits abstraction	Medium value; industrial, commercial & public service purposes (28/39/39/0225)
Licensed Chalk abstractions	High value; drinking water supply purposes (28/39/39/0226, 28/39/39/0080, 28/39/39/0209, 28/39/39/0229, 28/39/39/0141, 28/39/42/0072, 28/39/42/0074, 28/39/39/0006, 28/39/39/0046, 28/39/39/0212, 28/39/42/0076, 08/37/54/0062, 28/39/42/0073, 28/39/43/0019, 29/38/09/0113, 29/38/09/0201)
	High value; GSHP non-evaporative (heat pump or cooling) purposes (28/39/39/0238, 28/39/39/0232, TH/39/39/0004, 28/39/42/0033, 28/39/39/0157, 28/39/39/0008, 28/39/39/0236, 28/39/39/0005, 28/39/39/0013, 28/39/39/0139, 28/39/39/0016, 28/39/42/0062, TH/39/44/0007, 28/38/09/0149, 28/39/44/0003, 28/38/09/009)
	Medium value; industrial, commercial & public service (process water, amenity top up water, horticultural or irrigation) purposes (28/39/42/0048, 28/39/42/0004, 28/39/42/0002, 28/39/42/0069, 29/38/09/0177, 28/39/42/0070, 28/39/09/0187)

Construction base case

13.4.41 The construction base case in the assessment year includes the current baseline and also developments that are likely to have been completed and partially or fully operational during construction of the Thames Tideway Tunnel project, and which would have the potential to lead to a change in the setting in respect to groundwater resources in the upper and lower aquifers.

13.4.42 The construction base case includes the tunnels and underground infrastructure for the developments identified in Vol 3 Table 13.3.2. These may cause some disruption to groundwater flow in the upper aquifer where it is diverted around these structures. However, any impacts are expected to be highly localised. Any changes from the baseline conditions prior to construction would be detected by monitoring of groundwater levels in the upper aquifer.

13.4.43 The construction base case also includes the licensed abstractions for dewatering in the lower aquifer for the Thameslink and Crossrail developments, as identified in Vol 3 Table 13.3.2, as these are likely to be active at the time of construction of the Thames Tideway Tunnel project.

Operational base case

13.4.44 The operational base case includes the current baseline and also developments that are likely to have been completed and partially or fully operational during operation of the Thames Tideway Tunnel project, and which would have the potential to lead to a change in the setting in respect to groundwater resources in the lower aquifer.

13.4.45 The operational base case would include the planned tunnels and underground infrastructure for the developments identified in Vol 3 Table 13.3.3. These may cause some disruption to groundwater flow in the upper aquifer where it is diverted around the structures. However, any impacts are expected to be highly localised. Any changes from the baseline conditions prior to operation would be detected by monitoring of groundwater levels in the upper aquifer.

13.5 Construction effects assessment

Construction impacts

13.5.1 The proposed development has the potential to impact on groundwater resources, including the upper and lower aquifers and licensed abstractions, during construction due to:

a. dewatering of aquifer units (flows and levels)

b. mobilisation of poor quality groundwater (quality)

c. mixing of groundwater (quality)

d. use of grouts (quality)

e. physical disturbance (quality)

Dewatering of aquifers

13.5.2 No dewatering of the upper aquifer would be required for construction of the drop/main tunnel shafts or the tunnel route. Piling, jacked caissons or diaphragm walls would seal out of the River Terrace Deposits.

13.5.3 For shaft and connection tunnel construction in the central and eastern areas groundwater levels would have to be lowered by dewatering the lower aquifer to allow construction of the main tunnel shafts and CSO drop shafts. These sites are where either construction activities extend down into the lower aquifer, or the construction activities come close enough to the lower aquifer for them to be affected by the groundwater under high pressure, potentially causing heave effects (uplift).

13.5.4 No dewatering is anticipated to be required for the construction of the Main tunnel or long connection tunnels. The dewatering required for main tunnel TBM launch and reception are included with the shaft dewatering requirements.

13.5.5 For the connection tunnels in the central section, dewatering proposed at the sites associated with these connection tunnels (Cremorne Wharf Depot, Chelsea Embankment Foreshore, Heathwall Pumping Station, Albert Embankment Foreshore and Victoria Embankment Foreshore) would sufficiently lower groundwater levels for the construction of these tunnels and no additional dewatering is anticipated. Local depressurisation along the main tunnel or connection tunnel route would remain an option for the contractor but would not affect the overall impact. The volumes of dewatering at individual sites are presented in the site assessments and in Vol 3 Table 13.5.1.

13.5.6 Given that the aquifer is extensive, dewatering concurrently at a number of locations leads to a wide-scale lowering of groundwater levels and so reduces the need for pumping at any one location. The impacts at licensed abstractions within the lower aquifer have also been assessed on the basis of this concurrent dewatering.

13.5.7 The dewatering volumes required to enable construction of the drop shafts have been quantified by modelling (see Vol 3 Appendix K.2 Modelling report). A summary of the method of dewatering of the lower aquifer at sites and an estimate of the dewatering volumes is given in Vol 3 Table 13.5.1.

Vol 3 Table 13.5.1 Groundwater – summary of anticipated average dewatering volumes from lower aquifer

Area*	site	Dewatering method	Average rate of dewatering (m^3/d)
Central	Kirtling Street	Dewatering wells in Chalk of the lower aquifer (external)	440
	Albert Embankment Foreshore	Dewatering wells in Upnor Formation of lower aquifer (external)	Less than 200

Area*	site	Dewatering method	Average rate of dewatering (m^3/d)
	Blackfriars Bridge Foreshore	Dewatering wells in Chalk of lower aquifer (external)	1,085
Eastern	Chambers Wharf	Dewatering wells in Chalk of lower aquifer (internal)	Less than 200
	King Edward Memorial Park	Dewatering wells in Chalk of lower aquifer (internal)	Less than 200
	Earl Pumping Station	Dewatering wells in Chalk of lower aquifer (internal)	Less than 200
	Deptford Church Street	Dewatering wells in Chalk of lower aquifer (internal)	Less than 200
	Greenwich Pumping Station	Dewatering wells in Chalk of lower aquifer (internal)	Less than 200
	Abbey Mills Pumping Station	Dewatering wells in Chalk of lower aquifer (internal)	Less than 200
	Beckton Sewage Treatment works	Dewatering wells in Chalk of lower aquifer (internal)	Less than 200

** Construction activities do not extend into the lower aquifer at the western sites; therefore no dewatering of the lower aquifer is anticipated.*
*** Internal dewatering – pumps located inside a diaphragm wall in order lower water levels*

13.5.8 The impact of dewatering on groundwater resources in the lower aquifer has been quantified by comparing an estimate of the total dewatering volume with an estimate of the total licensed abstraction volume across the confined Chalk Water Resource Management Unit (WRMU) as set out in the *London Catchment Abstraction Management Strategy* (CAMS) (EA, 2006)[11].

13.5.9 The total licensed abstraction volume for the confined Chalk WRMU, in which the Thames Tideway Tunnel project is located, is estimated to be 86,000m^3/d (EA, 2009). Dewatering of the lower aquifer for the construction phase of the Thames Tideway Tunnel project is anticipated to be required at central sites only, where the Chalk aquifer is confined. Therefore the total dewatering volume from the confined Chalk WRMU over the construction phase of the Thames Tideway Tunnel project is estimated to be 1,630,000m^3 over 4 years. This equates to approximately 1,100m^3/d although dewatering would not be consistent over this time frame (see Vol 3 Appendix K.2). The total average dewatering volume equates to approximately 1% of the total licensed abstraction volume. The magnitude of impact has therefore been assessed as low.

13.5.10 The impacts on groundwater levels at licensed abstractions have been quantified by modelling (see Vol 3 Appendix K.2) and the effects are included in this assessment. The magnitude of impact assigned to each licensed abstraction receptor is based on the time-scale over which each receptor would be impacted (ie, temporary lowering of water levels) and on the magnitude of the maximum predicted drawdown as a result of dewatering compared with the maximum assessed available drawdown (MAAD)[xxii] for each licensed abstraction source.

13.5.11 Vol 3 Table 13.5.2 details the licensed abstraction receptors predicted by modelling to be impacted by dewatering and the assigned magnitude of impact. Further detail is provided in the modelling report (Vol 3 Appendix K.2).

Vol 3 Table 13.5.2 Groundwater – impacts on licensed abstractions

Area	Licence number	MAAD (m)	Maximum predicted drawdown (m)	No. of months exceeded	Magnitude of impact
Central	28/39/39/0226	15.0	5.73	-	Negligible
	28/39/39/0080	37.0	5.60	-	Negligible
	28/39/39/0209	25.0	5.76	-	Negligible
	28/39/39/0229	4.00	5.47	28	Medium
	28/39/39/0141	9.00	7.59	-	Low
	28/39/42/0072	9.70	8.55	-	Low
	28/39/42/0074	44.0	7.89	-	Negligible
	28/39/39/0046	20.0	5.18	-	Negligible
	28/39/39/0212	15.0	4.39	-	Negligible
	28/39/42/0076	6.10	3.78	-	Negligible
	28/39/39/0238	18.0	5.75	-	Negligible
	28/39/39/0232	11.0	6.12	-	Negligible
	TH/39/39/0004	26.0	5.91	-	Negligible
	28/39/42/0033	20.0	4.30	-	Negligible
	28/39/39/0157	24.6	4.44	-	Negligible
	28/39/39/0008	19.0	4.88	-	Negligible
	28/39/39/0236	18.0	4.41	-	Negligible
	28/39/39/0005	15.0	4.70	-	Negligible
	28/39/39/0013	35.0	5.35	-	Negligible
	28/39/39/0139	17.97	6.39	-	Negligible
	28/39/42/0062	34.0	3.52	-	Negligible
	28/39/42/0004	18.0	5.68	-	Negligible

[xxii] Maximum assessed available drawdown – the headroom within the borehole available to buffer the predicted drawdown impacts.

Area	Licence number	MAAD (m)	Maximum predicted drawdown (m)	No. of months exceeded	Magnitude of impact
	28/39/42/0069	20.0	5.02	-	Negligible
	28/39/42/0062	34.0	3.52	-	Negligible
	28/39/42/0070	30.0	6.25	-	Negligible
Eastern	08/37/54/0062	5.00	0.50	-	Negligible
	28/39/42/0073	13.0	1.64	-	Negligible
	28/39/43/0019	5.0	0.67	-	Negligible
	29/38/09/0201	10.0	0.50	-	Negligible
	TH/39/44/0007	20.0	0.67	-	Negligible
	28/39/44/0003	10.0	0.68	-	Negligible
	29/38/09/0149	115.0	0.56	-	Negligible
	28/39/42/0048 (Borehole A)	7.0	2.02	-	Negligible
	28/39/42/0048 (Borehole B)	16.0	2.04	-	Negligible
	29/38/09/0177	20.0	0.54	-	Negligible
	28/38/09/0009	17.0	0.53	-	Negligible
	29/38/09/0113	14.0	0.52	-	Negligible

13.5.12 The predicted impact is negligible for most of the licensed abstractions. A low impact is anticipated at 28/39/39/0141 (Mantilla Limited) and 28/39/42/0072 (Thames Water Utilities Limited), and a medium impact is anticipated at 28/39/39/0229 (Global Grange Limited).

Mobilisation of poor quality groundwater

13.5.13 Poor quality groundwater (with concentrations in exceedance of the Water Supply (Water Quality) Regulations and relevant EQS) has been identified within the upper aquifer across the western, central and eastern areas. However no dewatering of the upper aquifer is anticipated to be required in these areas. The likely significant effects as a result of the mobilisation of poor quality groundwater in the upper aquifer are addressed on a site by site basis as effects would be localised rather than at a project scale (see Vol 4-27 Section 13).

13.5.14 Several ‘hotspots’ of poor quality groundwater have been identified within the lower aquifer across the central and eastern areas. Dewatering of the lower aquifer could result in an increased hydraulic gradient towards dewatering wells and increased the groundwater flow velocities. Although based on the modelling (see Vol 3 Appendix K.2 Modelling report) undertaken to assess dewatering impacts, it is anticipated that any changes in groundwater flow velocities would be small. For example, the predicted velocities in the central area would change from approximately 177m/year to around 185m/yr under the proposed project dewatering. This is despite the changes in hydraulic gradient being greatest in the central areas. As a result, the increased potential for poor quality groundwater to migrate horizontally or vertically within the lower aquifer is considered to be small. Any increase in flow velocities as a result of dewatering are anticipated to be negligible. Therefore the magnitude of impact on the lower aquifer of mobilising poor quality groundwater is anticipated to be negligible.

13.5.15 The effects on water quality for sites where dewatering external to the diaphragm wall is proposed are assessed in the site-specific sections (Kirtling Street Vol 14 Section 13, Albert Embankment Foreshore Vol 16 Section 13 and Blackfriars Bridge Foreshore Vol 18 Section 13) and briefly summarised below.

13.5.16 In the case of Kirtling Street

a. There is known groundwater contamination within the lower aquifer in this location.

b. Dewatering of the lower aquifer at Kirtling Street would be high (approximately 2,700 m^3/d) for around 8 months while the base slab is being constructed. The change in hydraulic gradients and groundwater flow velocities are anticipated to be small (see para. 13.5.14). There is no abstraction source located between the boreholes in which contamination was identified and the Kirtling Street site, although the dewatering does has the potential to draw contamination into the SPZ1. The short period of intense dewatering means that the likely magnitude of impact as a result of mobilising the identified contamination is considered to be low.

13.5.17 In the case of Albert Embankment Foreshore

a. The main contamination identified locally lies within the lower aquifer, as described above.

b. Dewatering wells would be required within the Upnor Formation of lower aquifer, and external to the diaphragm wall. There would be limited dewatering at Albert Embankment Foreshore site, approximately 200 m^3/d, due in part to the close proximity of the site to Kirtling Street. The change in hydraulic gradients and groundwater flow velocities are anticipated to be small (see para. 13.5.14). There is unlikely to be any deterioration in groundwater quality resulting from the construction methods being used and therefore the impact is considered to be negligible.

13.5.18 In the case of Blackfriars Bridge Foreshore

a. There is no baseline groundwater quality data available for the Chalk (lower aquifer) in close proximity to the site.

b. The change in hydraulic gradients and groundwater flow velocities in the eastern areas are anticipated to be very small.

c. The dewatering at the Blackfriars Bridge site would be substantial at approximately 1,085m^3/day, however given the lack of data, the threat of mobilising contamination is considered to be negligible.

13.5.19 The magnitudes of impact described above are summarised in Vol 3 Table 13.5.3.

Vol 3 Table 13.5.3 Groundwater – summary of mobilising of poor quality groundwater impacts

Area	Lower aquifer and licensed abstractions in vicinity of site/ tunnel	Magnitude of impact
C,E	Lower aquifer	Negligible
C	Licensed abstractions close to Kirtling Street	Low
	Licensed abstractions close to Albert Embankment Foreshore	Negligible
E	Licensed abstractions close to Blackfriars Bridge Foreshore	Negligible

Note: Construction activities do not extend into the lower aquifer at the western sites and there are no anticipated effects of project-wide dewatering at Beckton Sewage Treatment Works; therefore no mobilisation of contamination within the lower aquifer is anticipated at these locations.

Mixing of groundwater

13.5.20 Dewatering of the lower aquifer may also induce natural groundwater mixing as a result of drawing down groundwater levels below the top of the Thanet Sand. The EA status report *Management of the London Basin Chalk Aquifer* (EA, 2010)[12] sets out the aim to manage abstraction licensing in the Chalk in order to keep groundwater levels above the Thanet Sands.

13.5.21 Drawing groundwater levels down below the top of the Thanet Sands may lead to reduced conditions[xxiii] and may result in the reduction of metals to insoluble forms (resulting in staining, blockages and sliming), conversion of naturally occurring pyrite (iron sulphide) to sulphate and conversion of nitrate to ammonium (resulting in odour and potential exceedances of Water Supply (Water Quality) Regulations).

13.5.22 The shaft and tunnel construction in the western area would not extend into the Thanet Sands and Chalk and so the impact of mixing of groundwater is not assessed for that area. No dewatering is anticipated to be required for tunnelling; therefore no impact on groundwater quality as a result of drawing down groundwater levels around the tunnel is anticipated.

[xxiii] Reduced conditions – when metals may come out of solution, thereby affecting groundwater quality. The opposite of oxidised conditions,

13.5.23 There are not anticipated to be any sites in the central area at which dewatering is anticipated to draw groundwater levels down below the top of the Thanet Sands.

13.5.24 At a majority of the eastern sites, there are not anticipated to be any significant drawing down of groundwater levels below the top of the Thanet Sands. Where the Thanet Sand has been dewatered historically in places and conditions are likely to be already changed, then any further deterioration of groundwater quality is unlikely to be significant. The two sites with these drawn down conditions are at the King Edward Memorial Park and Chambers Wharf sites.

13.5.25 The magnitude of impact has been assessed to be negligible for all sites in the central and eastern areas.

Use of grout

13.5.26 Minimal amounts of grouting are anticipated to be required within the upper aquifer, namely at Hammersmith Pumping Station, Falconbrook Pumping Station, Cremorne Wharf Depot and Chelsea Embankment Foreshore sites. Grout-contaminated groundwater is characterised by excess turbidity and essential additives. This impact with regard to shaft construction has been addressed in the respective site assessments (Vol 4-27 Section 13). As there would be no tunnel construction within the upper aquifer, this impact on the upper aquifer has not been considered further.

13.5.27 Tunnel construction would not extend into the lower aquifer within the western area (see Vol 3 Table 13.4.1). Therefore, the impact of grout on the lower aquifer within this area has not been considered further.

13.5.28 Ground treatment or grouting is anticipated to be required for the construction of fifteen of the shafts and around the connection points between these shafts and the main tunnel in the form of treated blocks to facilitate the TBM break out and break in to the shafts. The impacts of this grouting, which would be localised to the locations of the shafts has been addressed in the respective site assessments (Vol 4-27 Section 13).

13.5.29 Void grouting would also be required to fill any gaps between the tunnel rings and the ground and would be injected as the TBM advances. There is the potential for grout-contaminated groundwater to migrate along the outside of the tunnel and impact groundwater quality in the lower aquifer on a project-wide basis. As grout setting generally occurs on a timescale of a few minutes, in most circumstances the impact is likely to be localised although the magnitude of impact would depend on the direction of the tunnel drive (where grout is applied against the direction of groundwater flow it is less likely to migrate away from the location where it is applied) and the proximity to an abstraction.

13.5.30 The magnitude of impact has been assessed in accordance with the EA regulatory position statement *Civil engineering activities involving grouts or other media for the purpose of sealing or ground stabilisation* (EA, 2011)[13].

13.5.31 In the central area, void grouting is only likely to be required within the lower aquifer for the tunnel drive from Blackfriars Bridge Foreshore (the most easterly of the central sites) in an east-southeast direction towards Chambers Wharf. This section does not pass through any modelled SPZ1.

13.5.32 In the eastern area, void grouting is likely to be required within the lower aquifer for the main tunnel drive from Chambers Wharf to Abbey Mills Pumping Station (the main tunnel) and from Greenwich Pumping Station to Chambers Wharf (the Greenwich Connection Tunnel). The main tunnel drive does not pass through any modelled SPZ1 and the drive is perpendicular to the direction of regional groundwater flow, which is also considered to reduce the potential for migration. The Greenwich connection tunnel drive also does not pass through a modelled SPZ1, although the drive is in the direction of regional groundwater flow, which is considered to increase the potential for migration of grouts As grout setting generally occurs on a timescale of a few minutes, the impact is likely to be temporary (for a very short time) and localised. The magnitude of impact is summarised in Vol 3 Table 13.5.4.

Vol 3 Table 13.5.4 Groundwater – summary of void grouting impacts

Area	Site/ tunnel	Magnitude of impact
Central	Main tunnel	Negligible
Eastern	Main tunnel	Negligible
	Greenwich connection tunnel	Negligible

Note: Tunnelling construction activities do not extend into the lower aquifer at the western sites; therefore no grouting in the lower aquifer is anticipated here.

Physical disturbance

13.5.33 Tunnelling may result in the physical disturbance of the lower aquifer and deterioration in water quality as a result of elevated turbidity within the lower aquifer and at licensed abstractions during construction.

13.5.34 In the western and central areas, tunnelling would not extend into the Chalk; therefore no impacts of physical disturbance are assessed here.

13.5.35 In the eastern area, tunnelling would penetrate the lower aquifer. The magnitude of impact depends on the transmissivity of the Chalk, on the proximity to SPZ's and licensed abstractors.

13.5.36 The main tunnel does not pass through any SPZ's and the transmissivity of the Chalk is high (700 to 1,200m^2/d). The Greenwich connection tunnel passes into one SPZ, delineated for two Thames Water Utilities sources, and the transmissivity of the Chalk is very high (1,200 to 3,000m^2/d). The magnitudes of impact local to the tunnelling are anticipated to be of insufficient magnitude to affect the use or integrity of the lower aquifer and licensed abstractions and therefore assessed as negligible. The magnitudes of impact local to the tunnelling are summarised in Vol 3 Table 13.5.5.

Vol 3 Table 13.5.5 Groundwater – summary of physical disturbance impacts

Area	Tunnel	Magnitude of impact
Eastern	Main tunnel	Negligible
	Greenwich connection tunnel	Negligible

Note: Construction activities do not extend into the Chalk at the western and central sites.

Construction effects

13.5.37 By combining the impacts identified in paras. 13.5.1 - 13.5.36 above with the receptor importance in Vol 3 Table 13.4.8, the significance of the effects can be derived using the generic significance matrix (Vol 2 Section 2). The results are described in the following sections.

Dewatering of aquifers

13.5.38 The lower aquifer is considered to be of high value with regard to quantity on a project-wide basis.

13.5.39 A low impact has been assigned to the groundwater resource status of the lower aquifer, where the total dewatering volumes required are estimated to be approximately 1% of the total licensed annual abstraction volumes across the confined Chalk WRMU for four years. A low impact on a high value receptor for quantity would result in **moderate adverse** effect for the four years during which dewatering would be required.

13.5.40 A negligible impact has been assigned to the majority of the licensed abstractions, where the maximum predicted drawdown would not exceed the maximum assessed available drawdown (MAAD). A negligible impact on a medium value receptor (see Vol 3 Table 13.4.8) would result in a **negligible** effect. A negligible impact on a high value receptor (see Vol 3 Table 13.4.8) would result in a **minor adverse** effect.

13.5.41 A low impact has been assigned to two licensed abstractions, where the maximum predicted drawdown would not exceed the MAAD but would be within 20% of it. A low impact on high value receptors (28/39/39/0141 – Mantilla Limited - and 28/39/42/0072 – Thames Water Utilities Limited) would result in a **moderate adverse** effect for the period during which the predicted drawdown is within 20% of the MAAD (two and four months respectively). For the remainder of the construction period the effect on these receptors would be **minor adverse** (a negligible impact on a high value receptor).

13.5.42 A medium impact has been assigned to one licensed abstraction, where the maximum predicted drawdown would exceed the MAAD on a temporary basis. A medium impact on a high value receptor for quantity (28/39/39/0229 – Global Grange Limited) would result in a **major adverse** effect for approximately 28 months.

Mobilisation of poor quality groundwater

13.5.43 The lower aquifer is considered to be of high value with regard to quality. A temporary negligible impact on groundwater quality within the lower aquifer, as a result of mobilising poor quality groundwater by increasing hydraulic gradients in the lower aquifer, would result in a temporary **minor adverse** effect.

13.5.44 The effects on water quality at licensed abstractions as a result of mobilising poor quality groundwater by increasing hydraulic gradients in the lower aquifer are determined below:

a. A temporary (eight months) low impact as a result of the mobilisation of poor quality groundwater at Kirtling Street on a high value receptor would result in a **moderate adverse** effect.

b. A temporary negligible impact on the mobilisation of poor quality groundwater as a result of dewatering at Albert Embankment Foreshore and Blackfriars Bridge Foreshore, on a high value receptor would result in **minor adverse** effects in these two areas.

Mixing of groundwater

13.5.45 A negligible impact on groundwater quality in the lower aquifer, as a result of drawing down of groundwater levels below the top of the Thanet Sand and the deterioration of water quality by groundwater mixing would result in a **minor adverse** effect.

Use of grout

13.5.46 A negligible impact on groundwater quality in the lower aquifer, as a result of grouting for the main tunnel construction in the central and eastern areas and the Greenwich connection tunnel construction, on a high value receptor would result in a **minor adverse** effect.

Physical disturbance

13.5.47 A negligible impact on groundwater quality in the lower aquifer and on licensed abstractions, as a result of physical disturbance, would result in a **negligible** to **minor adverse** effects.

13.6 Operational effects assessment

Operational impacts

13.6.1 The proposed development has the potential to impact on groundwater resources at a project wide scale, including both the upper and lower aquifers and licensed abstractions, during operation due to:

a. physical obstruction (flows and levels

b. seepage from the tunnel (quality)

c. seepage into the tunnel (flows and levels)

d. reduction of pollution from storm water overflows to River Thames given the linkages between surface water and groundwater (quality)

Physical obstruction

13.6.2 The presence of the shafts and tunnels may disrupt groundwater flow and alter groundwater levels within both the upper and lower aquifers during the operational phase. This impact with regard to the shafts has been addressed in the respective site assessments (Vol 4-27 Section 13). No impacts are anticipated as a result of tunnelling within the western area and central area where tunnelling would be within the London Clay Formation and the Lambeth Group.

13.6.3 The presence of the tunnel at depth in the lower aquifer within the eastern area could disrupt groundwater flow locally. In this area, the alignment of the Greenwich connection tunnel is parallel to the direction of regional groundwater flow and therefore no impacts are anticipated. The alignment of the main tunnel in the eastern area between Chambers Wharf and Abbey Mills Pumping Station is across the direction of regional groundwater flow. Therefore the tunnel could potentially form a physical obstruction of up to 8.8m in external diameter.

13.6.4 While the Upper Chalk is up to 100m thick, the majority of inflows are in the top 30m (BGS, 1997). The eastern section of the main tunnel passes through the most productive section of the Chalk and could potentially reduce the thickness of this permeable horizon by up to 30% (8.8m/30m expressed as a percentage) along the length of the tunnel. However these impacts are anticipated to remain localised around the tunnel routes and groundwater flow is expected to deviate around the physical obstruction. Therefore the magnitude of this project-wide impact on groundwater flow is assessed to be negligible.

13.6.5 The presence of the shafts and tunnels within the lower aquifer would also reduce the aquifer resource in terms of storage and replace it with a sealed tunnel or shaft void space. The shafts and tunnels would only extend into the lower aquifer (Upnor Formation, Thanet Sands and Chalk) in part of the central area and across the eastern area. No impacts of storage loss are anticipated within the western area and within part of the central area where tunnelling would be within the London Clay Formation.

13.6.6 Based on hydraulic properties used within the distributed groundwater model developed for this quantitative assessment, the average storativity of the lower aquifer (Upnor Formation, Thanet Sands and Chalk) is 10^{-4} and the aquifer area (used in the EA London Basin model) is 2,400km^2 (EA, 2010). Therefore the total storage of the Chalk over this area is estimated to be 240,000m^3. The loss of storage and therefore water resources from the lower aquifer is conservatively estimated to be 160m^3 based on the depths to which the shafts extend into the lower aquifer, the shafts' external diameters and the lengths and external diameters of the main and connection tunnels. The magnitude of loss of aquifer resource during operation is assessed to be negligible.

Seepage from tunnel

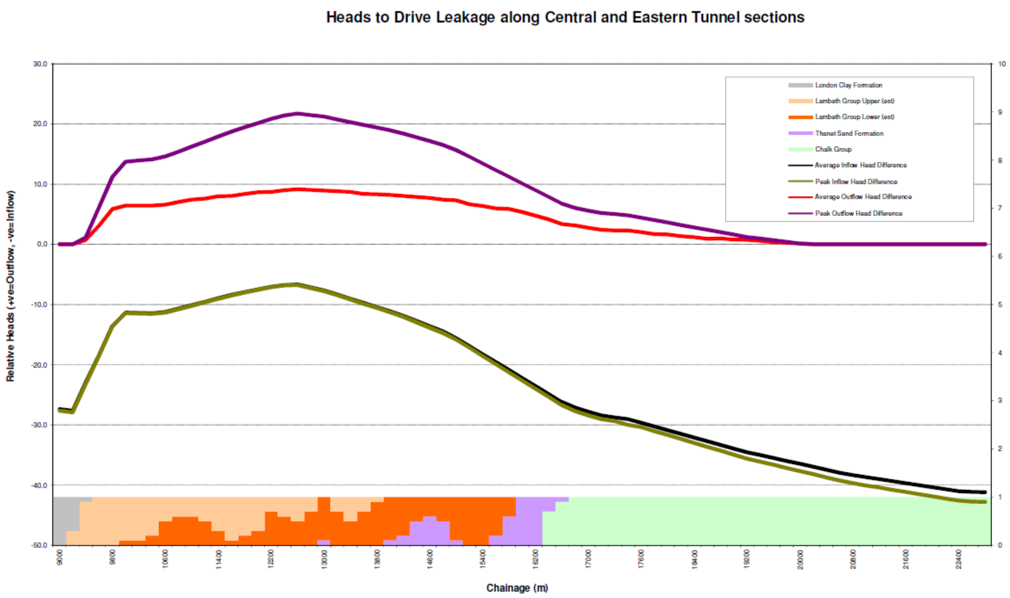
13.6.7 The impacts on groundwater quality as a result of seepage from the shafts would be localised rather than project-wide and have been addressed in the respective site assessments (Vol 4-27 Section 13). However, any seepage from the tunnel would have the potential to result in the deterioration of groundwater quality on a project-wide basis, impacting both the flow and quality in lower aquifer and at licensed abstraction sources.

13.6.8 No tunnel is completely watertight. The operation of the tunnel would be such that head (water pressure) differences between the tunnel and the surrounding aquifer are likely to develop and may produce limited inflows and outflows between the tunnel and groundwater. These gradients have the potential to result in inflows from the lower aquifer into the tunnel most of the time, although, at times of surcharge (or flood conditions ie, when full), hydraulic gradients would reverse and the potential for outflows from the tunnel into the lower aquifer would arise.

13.6.9 The potential for seepage across the tunnel lining would depend on three main factors. Firstly, the head (water pressure) difference between the tunnel and external groundwater heads; secondly, the leakage rate for a given type of lining, joints and seals; and thirdly, the ground permeability and presence of local fractures.

13.6.10 The green and red lines in Vol 3 Plate 13.6.1 are the peak and average outflow head differences respectively. These heads are calculated as the difference between the head in the tunnel (when full) and piezometric head in the lower aquifer. The head differences which could drive outflows from the tunnel into the lower aquifer are only beneficial within the central area, due to high heads within the Lambeth Group, and therefore there is potential for outflows along this section only. In addition, the tunnel is surcharged for around 3% of the time and the usual operating condition is empty; therefore the potential for outflows occurs 3% of the time along the central part.

Vol 3 Plate 13.6.1 Groundwater – inflow and outflow head difference



13.6.11 An assessment of the theoretical seepage volumes from the tunnel assumes that a lining would be in place with a rate of seepage of $1l/m^2/d$ Vol 2 Appendix K.3 (further detail provided in Vol 2 Section 13). The estimated annual seepage volume from the tunnel into the lower aquifer over the central area only, considering the tunnel is surcharged for around 3% of the time is approximately $2,100m^3$. If this figure is calculated as a daily outflow across the entire year, it equates to $5.8m^3/d$ over the central area which is approximately 8.6km in length. In this context, the magnitude of seepage from the operational tunnel to the lower aquifer, on both flow and quality, within the central area is assessed to be negligible.

Seepage into tunnel

13.6.12 The impact on aquifer resources as a result of seepage into the shafts would be localised rather than project-wide and has been addressed in the respective site assessments (see Vol 4-27 Section 13). However seepage into the tunnel has the potential to result in a loss of aquifer resource (quantity) from the lower aquifer. This impact is assessed for those areas where the tunnel would penetrate the lower aquifer ie, between Victoria Embankment Foreshore and Blackfriars Bridge Foreshore sites in the central area and all of the eastern area. There is no potential to cause deterioration of groundwater quality as a result of seepage into the tunnel.

13.6.13 The blue and black lines in Vol 3 Plate 13.6.1 are the peak and average inflow head differences respectively. Again these heads are calculated as the difference between the head in the tunnel (when full) and piezometric head in the lower aquifer. The head differences which could drive inflows into the tunnel from the lower aquifer are negative along the full length of the main tunnel between Victoria Embankment Foreshore and Blackfriars Bridge Foreshore sites in the central area and all of the eastern area and therefore there is potential for inflows along the full length of the main tunnel in these areas. The potential for inflows occurs 97% of the time as the tunnel would only be full 3% of the time.

13.6.14 An assessment of the theoretical seepage volumes into the tunnel assumes a rate of seepage of $1l/m^2/d$ (see Vol 2 Appendix K.3). The estimated loss of water resources from the lower aquifer as a result of seepage into the tunnel across these areas is $79{,}500m^3$/annum. If this figure is calculated as a daily outflow across the entire year, it equates to approximately $200m^3/d$ over this area of approximately 9.9km in length. In this context the magnitude of seepage into the tunnel from the lower aquifer along the main tunnel during operation is assessed to be negligible.

Reduction of pollution

13.6.15 The Thames Tideway Tunnel project as a whole would have significant benefits in terms of surface water quality in the London Basin and help to achieve the objectives of the Water Framework Directive (see Section 14 of this volume).

13.6.16 As detailed in para. 13.4.30, there is the potential for river water to enter the lower aquifer (EA, 2010) within the London Basin between Greenwich and Woolwich. This pathway has the potential to affect groundwater quality by introducing polluted river water into the lower aquifer. The baseline groundwater quality data shows exceedances of ammonia at central and eastern sites, which suggest that the lower aquifer is subject to anthropogenic inputs of ammonia. Ammonia may be present in groundwater as a result of sewage treatment plant effluent, products from soakaways, leaking sewers, or from the break-down of naturally occurring organic matter. Even at dilute concentrations ammonia is highly toxic to aquatic animals (EA, 2006)[14].

13.6.17 The substantial reduction of pollution from storm water overflows to the River Thames would have the potential to improve groundwater quality. However the volume of inflow from the River Thames into the aquifer remains unquantified and the magnitude of impact has been assessed to be negligible.

Operational effects

13.6.18 By combining the receptor value (See Vol 3 Table 13.4.8) with the impacts above, the significance of the effects can be derived using the generic significance matrix (Vol 2 Section 2). The effects are defined in the following sections.

Physical obstruction

13.6.19 The lower aquifer is considered to be of high value with regards to quantity. A negligible impact, as a result of physical obstruction and loss of aquifer storage within the lower aquifer, on a high value receptor, would lead to a **minor adverse** effect.

Seepage from tunnel

13.6.20 The impact of seepage into the tunnel is assessed to be negligible. The lower aquifer is considered to be of high value with regard to quality, therefore this would lead to a **minor adverse** effect.

Seepage into tunnel

13.6.21 The impact of seepage into the tunnel is assessed to be negligible. The lower aquifer is considered to be of high value with regard to quantity, therefore this would lead to a **minor adverse** effect.

Reduction in pollution

13.6.22 The lower aquifer is considered to be of high value. A negligible impact, as a result of the potential reduction in pollution from reduction in CSO discharges, on a high importance receptor, would lead to a **minor beneficial** effect.

13.7 Cumulative effects assessment

Construction effects

13.7.1 Two of the project-wide developments which have been identified in Vol 3 Table 13.3.3 (Crossrail and Northern Line Extension) could give rise to cumulative effects relevant to groundwater in the upper aquifer through the inclusion of underground structures. It is considered that although there may be impacts on groundwater level within the upper aquifer due to these developments, the impact is not expected to be significant and any substantive changes to the baseline conditions prior to construction would be detected by monitoring of groundwater levels in the upper aquifer.

13.7.2 Dewatering of up to 50,000m^3/d would be required for the Crossrail development during the construction phase for tunnelling purposes (TfL, 2012)[15] but only until 2017. The Crossrail route is nearest to the Thames Tideway Tunnel project route between Blackfriars Bridge Foreshore and Abbey Mills Pumping Station and the Greenwich connection tunnel, where dewatering for the Thames Tideway Tunnel project is likely to commence in early 2017 and running until early 2021. Therefore there is likely to be a short overlap of dewatering activities for both developments and also groundwater levels in the lower aquifer are unlikely to have fully recovered following dewatering for the Crossrail development.

Operational effects

13.7.3 No cumulative operation effects assessment is required as no development schemes would be under construction during operation of the Thames Tideway Tunnel project development. Therefore, the effects on groundwater during operation would remain as described in Section 13.6.

13.8 Mitigation

Mitigation of effects

13.8.1 The following section sets out further mitigation measures to be taken to address the likely significant effects identified within the assessment.

13.8.2 For the construction phase, significant adverse effects have been identified and are as follows:

a. effects on lower aquifer and on licensed abstractors as a result of lowering groundwater levels by dewatering

b. effects on licensed abstractors as a result of mobilising poor quality groundwater.

Mitigation of construction effects

13.8.3 Dewatering would cause a temporary **moderate adverse** effect on the lower aquifer for approximately four years. The mitigation could comprise of the use of techniques to reduce the volume of dewatering such as internal dewatering and increased ground treatment, such as ground freezing at sites where high volumes of dewatering is predicted (in particular the Kirtling Street site where volumes of up to 2,700m^3/d are predicted for an eight month period).

13.8.4 Project-wide dewatering would cause temporary **moderate adverse** effects on licensed abstractions 28/39/39/0141 (Mantilla Limited) and 28/39/42/0072 Thames Water Utilities Limited) (for four and two months respectively). The mitigation described in para 13.8.3 would serve to reduce the impact on licensed abstractions and may mean that effects are sufficiently reduced such that no further mitigation would be required. Should the mitigation detailed in para 13.8.3 not be sufficient a mitigation scheme for these abstraction licences would be required to ensure that these sources can continue to be used for the duration of the dewatering at the Kirtling Street site. The mitigation could comprise of lowering the pumps, deepening boreholes or, for 28/39/39/141 provision of an alternative supply. In the case of 28/39/42/72, this source is one of several sources operated by Thames Water and there is flexibility within its supply network which may mean that another source could be used for a short period, rather than provision of new supply. Further discussion with these abstraction licence holders to agree mitigation will take place after pumping tests on Kirtling Street site have been completed.

13.8.5 Project-wide dewatering would cause a **major adverse** effect on licensed abstraction 28/39/39/0229 (Global Grange Limited), for up to 28 months. The mitigation described in para 13.8.3 would serve to reduce the impact on licensed abstractions and may mean that effects are sufficiently reduced such that no further mitigation would be required. Should the mitigation detailed in para 13.8.3 not be sufficient a mitigation scheme for this abstraction licence would be required to ensure that the licensed source can continue to be used for the duration of project-wide dewatering. The mitigation could comprise of lowering the pump in the borehole with a modified pumping regime, should the groundwater levels fall below the existing pump depth; deepening of the borehole or provision of an alternative supply. Information gathered from the licence holder indicates that this abstraction source may be affected by poor water quality and which means its use for drinking water supplies is prevented. Monitoring ahead of and during construction may be sufficient mitigation, if it is the found the abstraction source is not currently usable.

13.8.6 To mitigate the effects on the licensed abstractions and the lower aquifer in general, it is proposed to only lower water levels by an amount that keeps the required excavation depth dry at any point (ie dewatering to maximum shaft depths would be done for the shortest practical period). The use of internal dewatering, rather than external dewatering, at Kirtling Street, Albert Embankment Foreshore and Blackfriars Bridge Foreshore would substantially reduce the volume of water that would need to be pumped. This would reduce the assessed effect on the lower aquifer.

13.8.7 Mobilisation of poor quality groundwater would cause a temporary **moderate adverse** effect on licensed abstractions close to the Kirtling Street site. The mitigation for this site would be as per that proposed for the dewatering effects ie internal dewatering and increased ground treatment, possibly with ground freezing.

13.8.8 The groundwater monitoring strategy (Vol 3 Appendix K.1) is part of the overall project-wide mitigation. A comprehensive network of monitoring boreholes has been installed in both the upper and lower aquifers. The ongoing monitoring of groundwater levels and groundwater quality would detect any substantive changes from the baseline conditions during both the construction and operational phases.

13.9 Residual effects assessment

Construction effects

13.9.1 The shafts and the tunnelling do not extend into the lower aquifer within the western area. Therefore no project-wide construction effects on groundwater resources are anticipated here.

13.9.2 The residual effects have been assessed to be **minor adverse** (the high value of the lower aquifer means that even a negligible impact has an overall minor adverse effect). All residual effects are presented in Section 13.10.

Operational effects

13.9.3 The shafts and the tunnelling do not extend into the lower aquifer within the western area. Therefore no project-wide operational effects on groundwater resources are anticipated here.

13.9.4 As no mitigation measures are proposed, the residual operational effects remain as described in Section 13.6. All residual effects are presented in Section 13.10.

13.10 Project-wide effects assessment summary

Vol 3 Table 13.10.1 Groundwater – summary of project-wide construction assessment

Effect	Area*	Receptor	Significance of effect	Mitigation	Significance of residual effect
Dewatering and lowering of groundwater levels in lower aquifer	C,E	Lower aquifer as a groundwater resource	Moderate adverse	Reduction in the volume of dewatering at the sites where higher volumes of dewatering are predicted. This could be achieved through the use of internal dewatering (at Kirtling Street, Albert Embankment Foreshore and Blackfriars Bridge Foreshore) additional ground treatment, such as grout or ground freezing. These measures are subject to site specific pump tests.	Minor adverse**
	C,E	Lower aquifer (and licensed abstractors)	Minor adverse to major adverse	**28/39/39/0141 (Mantilla Limited)** and **28/39/39/0229 (Global Grange Limited)** lower pump, deepen the borehole or provide an alternative supply. **28/39/42/0072 (Thames Water Utilities Limited)**, use of an alternative Thames Water source. All these measures are subject to discussions with individual licence holders. Internal dewatering (at Kirtling Street, Albert Embankment Foreshore and Blackfriars Bridge Foreshore)	Minor adverse**

Effect	Area*	Receptor	Significance of effect	Mitigation	Significance of residual effect
Mobilisation of poor quality groundwater in the lower aquifer, resulting in a deterioration in water quality	C	Lower aquifer (and licensed abstractors)	Negligible to moderate adverse	Internal dewatering and the increased use of ground treatment techniques at Kirtling Street, such as increased grouting or ground freezing. These measures are subject to the outcome of site specific pump tests at Kirtling Street and further ground investigation to better understand the identified contamination.	Minor adverse**
	E		Minor adverse	None	Minor adverse**
Mixing of groundwater resulting in a deterioration in water quality in the lower aquifer	C	Lower aquifer (and licensed abstractors)	Minor adverse	None	Minor adverse**
Use of grout in the lower aquifer resulting in a deterioration in water quality	C	Lower aquifer (and licensed abstractors)	Minor adverse	None	Minor adverse**
	E		Minor adverse	None	Minor adverse**

Effect	Area*	Receptor	Significance of effect	Mitigation	Significance of residual effect
Physical disturbance of the lower aquifer leading to a deterioration in water quality	E	Lower aquifer (and licensed abstractors)	Negligible to minor adverse	None	Minor adverse**

Note: C – Central area, E – Eastern area
** No project-wide effects on groundwater resources in the lower aquifer anticipated within the western area of the tunnel route (see Vol 3 Table 13.4.5*
*** Given the structure of the generic significance of effects matrix, the high value of the lower aquifer means that effects are always at least minor adverse.*

Vol 3 Table 13.10.2 Groundwater – summary of project-wide operational assessment

Effect	Area*	Receptor	Significance of effect	Mitigation	Significance of residual effect
Physical obstruction and loss of aquifer storage to groundwater flow	C, E	Lower aquifer	Minor adverse	None	Minor adverse**
Deterioration in water quality by seepage from tunnel	C	Lower aquifer (and licensed abstractors)	Minor adverse	None	Minor adverse**
Loss of aquifer storage by seepage into tunnel	C, E	Lower aquifer	Minor adverse	None	Minor adverse**
Improvement of water quality by reduction of pollution	C, E	Lower aquifer (and licensed abstractors)	Minor beneficial	None	Minor beneficial

Note: C – Central area, E – Eastern area

** No project-wide effects on groundwater resources in the lower aquifer anticipated within the western area of the tunnel route (see Vol 3 Table 13.4.5).*

*** Given the structure of the generic significance of effects matrix, the high value of the lower aquifer means that effects are always at least minor adverse.*

13.11 Summary of significant effects at all sites

13.11.1 No significant adverse effects on groundwater have been identified at any of the Thames Tideway Tunnel project sites beyond those presented in this project-wide assessment. As no further significant effects are anticipated, no further mitigation measures have been proposed and therefore the significance of residual effects would remain unchanged.

References

[1] Defra. *National Policy Statement for Waste Water* (2012).

[2] Environment Agency*. Introducing pollution prevention: PPG 1 – EA Consultation* (2011).

[3] Environment Agency and ESI. *London Basin Aquifer Conceptual Model.* ESI Report Reference 60121R1 (June 2010).

[4] Environment Agency. *Groundwater Quality Review: The Confined Chalk of the London Basin, Thames Region* (2006).

[5] Natural England. www.naturalengland.org.uk/images/18-upper-thames_tcm6-14425.pdf (January 2011).

[6] Environment Agency. *REACH Annex XVII Restrictions Polycyclic-aromatic Hydrocarbons (PAHs) Guidance Note Part 1* (October 2010). Available at: http://www.environment-agency.gov.uk/static/documents/Business/Part_1_PAH_Guidance_Note.pdf

[7] Commission of the European Communities. *Directive of the European Parliament and of the Council on environmental quality standards in the field of water policy and amending Directive 2000/60/EC* (2009). Available at: http://ec.europa.eu/environment/water/waterdangersub/pdf/com_2006_397_en.pdf?lang=_e.

[8] Environment Agency. *Groundwater Quality Review: The Thames Valley Gravels, Thames Region* (2006).

[9] Environment Agency. *Management of the London Basin Chalk Aquifer* (2010).

[10] Environment Agency*. River Basin Management Plan, Thames River Basin District* (December 2009). Available at: http://publications.environment-agency.gov.uk/PDF/GETH0910BSWA-E-E.pdf.

[11] Environment Agency. *The London Catchment Abstraction Management Strategy*. Final Strategy Document (2006).

[12] Environment Agency. *Management of the London Basin Chalk Aquifer* (2010)

[13] Environment Agency. *Civil engineering activities involving grouts or other media for the purpose of sealing or ground stabilisation*. Regulatory position statement (June 2011). Available at: http://www.environment-agency.gov.uk/static/documents/Business/MWRP_RPS_108_Grouting_media.pdf.

[14] Environment Agency. *Information about your groundwater quality analysis results* (2006).

[15] Transport for London. *Crossrail works programme*. Available at: http://www.crossrail.co.uk/railway/timeline. Accessed August 2012.

Thames Tideway Tunnel
Thames Water Utilities Limited

Application for Development Consent

Application Reference Number: WWO10001

Environmental Statement

Doc Ref: **6.2.03**

Volume 3: Project-wide effects assessment

Section 14: Water resources - surface water

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

Hard copy available in

Box **17** Folder **A**
January 2013

Thames Tideway Tunnel
Creating a cleaner, healthier River Thames

This page is intentionally blank

Thames Tideway Tunnel

Environmental Statement

Volume 3: Project-wide effects assessment

Section 14: Water resources – surface water

List of contents

Page number

List of plates

Page number

List of tables

Page number

14 Water resources – surface water

14.1 Introduction

14.1.1 The primary objective of the Thames Tideway Tunnel project is to capture discharges from combined sewer overflows (CSOs) into the tidal reaches of the River Thames (tidal Thames). This would ensure that the requirements of the EU Urban Waste Water Treatment Directive (UWWTD)[1] and the related UK Urban Waste Water Treatment Regulations (UWWTR)[2] are met. The UK is currently in infringement of parts of the UWWTD because of inadequate control of CSO discharges to the tidal Thames. Should nothing be done to address the current situation, continuing population growth and incremental increases in the area of impermeable surfaces across London are expected to increase the volume and frequency of CSOs discharges to the river. Such increased discharges would have associated increased adverse environmental impacts.

14.1.2 The European Court of Justice ruled in October 2012 that the UK is in breach of the UWWTD as regards collecting systems serving London (Beckton and Crossness), and treatment facilities serving London (Mogden, Beckton and Crossness STWs). Any further action will be determined by reference to the perceived adequacy of the UK's response, but the Commission is aware of the improvements already underway and the proposed construction of the Thames Tideway Tunnel. Progress with the Thames Tideway Tunnel is considered essential to limit the possibility of further enforcement, including substantial fines.

14.1.3 The Thames Tideway Tunnel project ensures progress towards meeting the objectives of the Water Framework Directive[3] (WFD). *The River Basin Management Plan* (RBMP) (EA, 2009)[4] developed for the River Thames as part of the requirements of the WFD, states that the London Tideway Tunnels[i] and the proposed sewage works upgrades projects "represent the primary measures to address point source pollution from the sewer system and are fundamental to the achievement of good status in this catchment (Estuaries and Coastal Waters Catchment)".

14.1.4 This section presents the findings of the assessment of the likely significant project-wide effects on surface water. The assessment includes the following:

a. identification of existing surface water resources baseline conditions

b. determination of base case conditions against which the proposed development has been assessed

c. assessment of significant effects of the proposed development during construction and operation

[i] The London Tideway Tunnels comprises two separate projects: the Lee Tunnel project and the Thames Tideway Tunnel project, which will be developed separately.

d. identification of mitigation measures and the residual effects both during construction and operation.

14.2 Proposed development relevant to surface water

14.2.1 The proposed development is described in Section 3 of this volume, with further details of each site described in Section 3 of Vols 4 to 27 Section 14. A summary of significant effects identified at the site-specific level across the project is provided in Section 14.11.

14.2.2 The elements of the proposed development relevant to surface water are set out below.

Construction

14.2.3 Some of the Thames Tideway Tunnel project sites are mainly located within the tidal Thames, which means that some of the proposed working areas would be within the river bed. The following construction activities have been identified as having the potential to cause impacts at a project wide level and could impact water quality in the river, primarily through disturbing sediments:

a. dredging

b. piling (including cofferdam construction)

c. campshed construction

d. barge operations

e. loss of material (excavated material and fill material supplied) during transfer to barges.

14.2.4 Dredging would be carried out using the backhoe method at the Blackfriars Bridge Foreshore, Carnwath Road Riverside and Kirtling Street sites. A proportion of the dredged material could be lost to the tidal Thames.

14.2.5 The disturbance of sediments as a result of these activities could lead to increased levels of suspended sediments within the tidal Thames.

14.2.6 The construction of in-river structures at some foreshore sites would affect the river regime with the potential that localised changes in flow velocity could cause scour of the river bed and foreshore, or deposition of sediments. The scour could occur around the face of the cofferdam or at adjacent bridge supports (abutment scour) or across the channel width (contraction scour). Any potential scour development during construction would be monitored and if relevant trigger levels are reached, appropriate protection measures would be provided. Further details are provided in *Scour Monitoring and Mitigation Strategy* (see Vol 3 Appendix L.4).

14.2.7 It is estimated that the project could create approximately 4,250 construction jobs, of which an estimated 13%, or 553 workers, would come from outside the Greater London area and therefore contribute additional wastewater flows to the sewer network (see Section 8 of this volume for details of proposed employment figures for the project).

Code of construction practice

14.2.8 At some sites there is a direct pathway for pollutants to be discharged to the tidal Thames due to the location of part of the construction area within the river channel. Other sites have an indirect pathway to the tidal Thames via surface water drains. The *Code of Construction Practice (CoCP)*[ii] Part A (Section 8) includes a number of measures to minimise the potential for impacts to surface waters, including impacts such as discharge of pollutants via surface water drains, and these are summarised below in paras 14.2.8 to 14.2.10.

14.2.9 Appropriate drainage, sediment and pollution control measures are included in the *CoCP* Part A (Section 8) in accordance with the relevant *Pollution Prevention Guidelines* (PPGs) issued by the Environment Agency (EA) and other Construction Industry Research and Information Association (CIRIA) documents.

14.2.10 All site drainage would be drained and discharged to mains foul or combined sewers (with settlement measures applied as required). Where this is not practicable, the site would be drained such that accumulating surface water would be directed to holding or settling tanks, separators and other measures prior to discharge to the surface water drains. Foul drainage from the site welfare facilities would be connected to the mains foul or combined sewer.

14.2.11 Suitable spill kits would be provided and positioned in vulnerable areas, staff would be trained in their use and a record would be kept of all pollution incidents or near-misses, to ensure appropriate action is taken and lessons are learned from any incidents. Regular 'toolbox talks' would be held to raise staff awareness of pollution prevention and share lessons learned from any recorded incidents. There would be written procedures in place for dealing with spillages and pollution (the *Pollution Incident Control Plan* or *PICP*).

Operation

14.2.12 The operation of the main tunnel would enable the control and subsequent treatment of a high proportion of the combined sewage generated during storms which would otherwise discharge to the tidal Thames from the CSOs. There would therefore be a reduction in the frequency, duration and volume of spills from the CSOs and this impact and subsequent effects are assessed in the following sections.

14.2.13 The new permanent structures in the river at some foreshore sites would affect the river regime with the potential that localised changes in flow velocity cause scour of the river bed and foreshore, or deposition of sediments. The effect of the permanent works on existing third party structures (ie, bridges and flood defences) would be monitored and if relevant trigger levels are reached, appropriate protection measures would be agreed with the owner of the structure. Further details are provided in

[ii] The *Code of Construction Practice* (CoCP) is provided in Vol 1 Appendix A. It contains general requirements (Part A), and site specific requirements for this site (Part B).

the *Engineering Design Statement,* which accompanies the application for development consent (the 'application').

14.3 Assessment methodology

14.3.1 The methodology for preparing the project-wide assessment is described in Volume 2 Environmental assessment methodology Section 14. Engagement and methodological assumptions and limitations of specific relevance to the project-wide effects assessment are detailed below.

Engagement

14.3.2 Vol 2 documents the overall engagement which has been undertaken in preparing the *Environmental statement*. Vol 2 Section 14 summarises the engagement that has been undertaken for the surface water assessment and the consultation responses relevant to surface water.

14.3.3 Engagement comments of relevance to the surface water project-wide assessment were received through discussion with the EA and are summarised in Vol 2 Section 14.

Water quality modelling

14.3.4 The impact of the proposed development on water quality was simulated using two modelling packages, the InfoWorks CS wastewater modelling package and the QUESTS river water quality modelling package (see Vol 3 Appendix L.1 for further detail of the modelling and outputs).

14.3.5 The InfoWorks CS wastewater models were developed by Thames Water and are used to simulate conditions within the sewer network and flows arriving at the five sewage treatment works (STWs) (Mogden, Beckton, Crossness, Long Reach and Riverside) and to the CSOs. For the purposes of this assessment, these models are referred to as the catchment models. The catchment models represent dry weather flow[iii] (DWF), storm flow and water quality conditions in each STW catchment's main sewer network. The models also predict the frequency, volume and duration of CSO spills in response to rainfall events.

14.3.6 The QUESTS river water quality model comprises hydrodynamic and water quality components, developed by WRc for the EA. It is a 1D time-series model of the Thames Estuary from Teddington Weir to the sea at Southend. The QUESTS model predicts effects on the DO levels of the tidal Thames from CSO discharges and STW discharges as well as changes climate and in natural river processes.

14.3.7 The InfoWorks CS catchment models and the QUESTS river water quality model have been used to describe the operation and effects of the CSOs on the tidal Thames. The two models are used to define the baseline, the base case and development cases in the five scenarios described below:

a. Scenario 1: to describe the current operation of the CSOs (baseline conditions) a modelled scenario has been used. This has been

[iii] Dry weather flow is foul water flow contribution during periods of dry weather

modelled as a scenario which uses 2006 population numbers with current sewage works capacities.

b. Scenario 2: to describe the base case, a 2021 modelled simulation has been used. This scenario includes the impact of predicted population increases and the proposed sewage works upgrades at Mogden, Beckton, Crossness, Long Reach and Riverside STWs and the operation of the Lee Tunnel.

c. Scenario 3: to describe the development case, a 2021 modelled simulation has been used that includes predicted population increases, the proposed sewage works upgrades, the operation of the Lee Tunnel and the operation of the Thames Tideway Tunnel project.

d. Scenario 4: to describe the 2080 base case without the Thames Tideway Tunnel project, a fourth simulation has been used that includes predicted 2080 conditions including population estimates, tidal level change and estimated river flow conditions. This scenario also, assumes that the Lee Tunnel and proposed sewage works upgrades are in place.

e. Scenario 5: to show the effects of climate change, a fifth modelled simulation has been used that includes predicted 2080 conditions including population estimates tidal level change and estimated river flow conditions. This scenario assumes that the Lee Tunnel, proposed sewage works upgrades and Thames Tideway Tunnel project are all in place.

14.3.8 The CSO performance (characterisation) for the five scenarios above has been assessed against the rainfall data for the Typical Year. The Typical Year is a single water year from October 1979 to September 1980 selected from the 1970 to 2011 rainfall records and best represents the average rainfall over the Beckton and Crossness catchment.

14.3.9 The scenarios described above have also been assessed against 242 summer rainfall events that would have an impact on dissolved oxygen (DO) levels in the tidal Thames. These summer rainfall events were established during the *Thames Tideway Strategic Study* (*TTSS*) and are known as the Compliance Test Procedure (CTP) rainfall series. The CTP has been used to demonstrate current levels of compliance with the *TTSS* DO standards. The 242 summer rainfall events were selected from 1970 to 2010 (41 years). The 242 CTP rainfall events were simulated using InfoWorks and the CSO discharges and STWs effluent discharges processed for the QUESTS water quality model to simulate the impact of these events on the tidal Thames under current baseline conditions.

Assumptions and limitations

Assumptions

14.3.10 Tidal Thames specific DO standards were developed as part of the *TTSS* based on the specific requirements of fish species reliant on the tidal Thames. The DO standards developed for the *TTSS* are to evaluate longer term compliance and environmental health and are a supplemental to those suggested by the WFD (see Vol 3 Appendix L.1). The *TTSS* standards were set at a level that would provide protection against more extreme DO reductions that can occur in water bodies affected by intermittent discharges, such as the tidal Thames. The *TTSS* DO standards were developed with reference to the Fundamental Intermittent Standards (FIS) described in the Urban Pollution Management Manual (UPM) and as such are consistent with the recommendations of the UKTAG WFD Guidance.

14.3.11 The assessment year for construction is Year 1 of construction (2016) when construction would commence. As no modelled water quality data are available for this year, the water quality conditions for the base case have therefore been derived from available modelled simulation data which uses population projections for 2021. This assumption is considered reasonable as substantial changes in water quality are considered unlikely between 2016 and 2021. It is also assumed that the modelled water quality conditions derived from population projections for 2021 are also reasonable for Year 1 of operation.

14.3.12 Where a proportion of the dredged material could be lost to the water column, the assessment assumes a 5% loss of material from the proposed backhoe dredging method.

14.3.13 In order to assess the impact of foul sewage flows produced by project workers during the construction phase, it has been assumed that some of the jobs created by the project would go to people living outside the Greater London area. This is assumed to be approximately 13% or 553 workers (see Section 10 for the full details of employment figures for the project).

14.3.14 In order to estimate the volume of sewage derived litter discharged to the tidal Thames from the CSOs, it has been assumed that litter tonnages are proportional to discharge volumes.

Limitations

14.3.15 For this project-wide assessment the only surface water receptor considered is the tidal Thames. Whilst the CSO discharges currently have an effect on the quality of the tidal tributaries through the overall movement of tidal water, the primary effect is on the tidal Thames and the QUESTS water quality model simulations used for the prediction of the current conditions and base case is only calibrated for the tidal Thames.

14.3.16 CSO and STW discharges to the tidal Thames were simulated using the InfoWorks CS wastewater modelling package and the dissolved oxygen profile along the tidal Thames were simulated using the QUESTS river water quality modelling package. The EA has assessed the QUESTS model to be suitable for comparison of option performance. The process and analysis of using both InfoWorks and Quests for the DO standard compliance has been agreed with EA as part of the *TTSS*.

14.3.17 The geographical limit of the calibrated QUESTS water quality model has been used as the geographical limit of this assessment ie, Teddington Weir to Mucking Flats. The sections of the tidal Thames are shown in Vol 2 Figure 14.4.1 (see separate volume of figures). There could potentially be impacts from the proposed development on other waterbodies (most notably the Thames Lower waterbody, see para. 14.4.3 below), but this has not been assessed due to the geographical limit of the calibrated QUESTS water quality model.

14.3.18 Transitional waters (ie, the tidal Thames) only have WFD water quality standards derived for DO and total inorganic nitrogen. The modelling undertaken to support this assessment has been based on DO effects.

14.4 Baseline conditions

14.4.1 The following section sets out the baseline conditions for surface water within the assessment area. Future baseline conditions (base case) are also described.

Current baseline

Water quality

14.4.2 Water quality standards have been developed for the WFD, which waterbodies are required to meet in order to attain ‘good’ status (or good potential). These standards have been considered in this assessment. The overall classification of status or potential under the WFD is a detailed process, which includes an assessment of water quality, physico-chemical, and hydromorphological elements. Reference should be made to the UKTAG[5] guidance, as given in the RBMP (EA, 2009)[6]. It should be noted for transitional waters and estuaries (i.e. the tidal Thames) only DO and total inorganic nitrogen standards have been developed for the WFD.

14.4.3 The RBMP recognises that some waterbodies may not achieve good status, due to modifications such as flood defence or navigation. In these cases, the waterbody is classified as an artificial waterbody (AWB) or heavily modified waterbody (HMWB) and has a target of good potential rather than good status. The Thames Tideway is classified as a heavily modified waterbody.

14.4.4 The status of the tidal Thames is defined by the Thames RBMP and is shown below in Vol 3 Table 14.4.1 below. The Thames RBMP divides the tidal Thames into three sections (or waterbodies) based on morphological and chemical characteristics, as follows:

a. Thames Upper – Teddington to Battersea Bridge

b. Thames Middle – Battersea Bridge to Mucking Flats

c. Thames Lower – Mucking Flats to Southend.

14.4.5 The three sections of the tidal Thames are shown in Vol 2 Figure 14.4.1 (see separate volume of figures)

14.4.6 Only the Thames Upper and Thames Middle waterbodies have been considered in this assessment owing to the geographical limit of the calibrated QUESTS water quality model used in this assessment.

Vol 3 Table 14.4.1 Surface water – receptors

Waterbody Name/ID	Hydromorphological status	Current ecological quality	Current chemical quality	2015 Predicted ecological quality	2015 Predicted Chemical Quality	2027 target status
Thames Upper GB530603911403	Heavily modified	Moderate potential	Pass	Moderate potential	Pass	Good potential
Thames Middle GB530603911402	Heavily modified	Moderate potential	Fail	Moderate potential	Fail	Good potential

Current baseline: CSO characterisation

14.4.7 The modelling of current baseline conditions (modelled as scenario 1 above in para. 14.3.7) predicts that in the Typical Year, the current CSO operation would result in approximately 39,600,000 m^3 of combined sewage entering the river annually. The locations at which this volume is discharged vary spatially, as shown in Vol 3 Table 14.4.2 below. See Section 14 in Vols 4 to 27 and Vol 3 Appendix L.1 for site-specific volumes discharged from the individual CSOs per annum.

Vol 3 Table 14.4.2 Surface water – Annual Typical Year CSO spills current baseline conditions*

Reach	Spill volume (m^3)	Maximum number of spills	Maximum spill duration (hrs)
Teddington to Putney Bridge	2,630,000	51	650
Putney Bridge to London Bridge	6,100,000	42	346
London Bridge to Greenwich	11,200,000	51	672
Greenwich to Henley Road (including Abbey Mills)	19,400,000	56	873
Henley Road to Crossness	308,000	5	27
TOTAL / MAXIMUM	**39,600,000**	**56**	**873**

*Note: * Figures are for the Typical Year under the 2006 current conditions modelled scenario ie, Scenario 1*

14.4.8 The start of CSO spills to the river during rainfall usually occur at the same time or within several hours of each other. Therefore, the frequency and spill duration in a reach are calculated as the maximum number of spill events and hours that at least one CSO within the reach is discharging. A new spill event is counted when there has been at least a 24 hour continuous dry period between the end of current CSO spill and start of a new CSO spill. Therefore the spill events as defined in Vol 3 Table 14.4.2 above could cover a time frame of several days. The CSO spill duration, however is the actual total hours with CSO discharge.

14.4.9 Modelling shows that discharges can occur from a CSO for a maximum of at least 873 hours in the Typical Year. The modelling also shows that the frequency of spills is greatest at Abbey Mills where the CSO spills 56 times per year under the current baseline (the Beckton STW expansion and the Lee Tunnel, currently under construction, are designed to control these spills), followed by Hammersmith Pumping Station, where the CSO spills 51 times per year under the current baseline (see Vol 3 Table 14.4.4).

14.4.10 The following sections consider the current baseline conditions for three of the key variables which are addressed by the Thames Tideway Tunnel project:

a. exposure to pathogens

b. sewage-derived litter

c. dissolved oxygen.

Exposure to pathogens

14.4.11 Each discharge increases the risk of exposure to pathogens for river users who come into contact with the water. An assessment of health impacts upon recreational users of the River Thames was conducted and reported by the Health Protection Agency in 2007 (City of London Port Health Authority & Health Protection Agency, 2007)[7]. The study concluded that risk of infection can remain for two to four days following a CSO spill as the water containing the spill moves back and forward with the tide[iv]. The same study also noted that analysis of the illness events reported against discharges on the tidal Thames showed that 77% of cases related to rowing activities undertaken within three days of a CSO discharge.

14.4.12 The modelled frequency of spills vary spatially along the tidal Thames; however, as an indicative measure of the likely risk of exposure to pathogens, the CSOs with the greatest number of spills in the Typical Year are assessed for risk days per section of river. The results are shown in Vol 3 Table 14.4.3 below, and demonstrate that as a maximum, recreational users are at a risk of exposure to pathogens in the tidal Thames for up to two thirds of the Typical Year as a result of combined sewage entering the river.

[iv] In a fluvial (ie, non-tidal) watercourse a CSO spill would be carried away by the river flow, however in the tidal environment of the Tidal Thames a spill would be carried downstream on an ebb tide but then be washed back upstream by the flood tide. The pathogens would therefore remain in the vicinity of the outfall for two to four days, leading to the risk of infection for water users also remaining for two to four days.

Vol 3 Table 14.4.3 Surface water – indicative number of risk days current baseline conditions

Location	CSO with greatest spill frequency	Number of spills	Indicative risk days range
Teddington to Putney Bridge	Hammersmith Pumping Station	51	102 – 204
Putney Bridge to London Bridge	Falconbrook Pumping Station	42	84 – 168
London Bridge to Greenwich	Greenwich Pumping Station	51	102 - 204
Greenwich to Henley Road	Abbey Mills Pumping Station	56	112 - 224
Henley Road to Crossness	Crossness Storm Tanks	5	10 - 20

Note: Figures are from different locations in the tidal Thames in the Typical Year under the 2006 current conditions modelled scenario ie, Scenario 1

Sewage derived litter

14.4.13 The operation of the existing CSOs along the tidal Thames results in the discharge of sewage litter along with the discharge of sewage. The impacts of sewage derived litter vary along the tidal Thames, with greater visual and aesthetic impacts experienced in the western reaches ie, in the Thames Upper waterbody.

14.4.14 It was estimated by the *TTSS* Steering Group Report (Thames Water, 2005)[8] that overflows from the combined sewers introduce approximately 10,000t of sewage derived solid material to the tidal Thames annually.

Dissolved oxygen

14.4.15 The continuous discharges of treated effluent from Crossness, Beckton, Riverside, and Long Reach STWs have the effect of causing a continuous DO ‘sag’ in the middle reaches of the tidal Thames. Mogden STW also has a similar effect in the upper reaches of the tidal Thames. The ‘sag’ is defined as a lowering of DO levels in the water as a result of the oxygen demand asserted by the BOD and ammonia in the effluent discharges ie, even under normal conditions the treated discharges from the STWs cause this DO sag. Examples of these DO sags were provided by the EA and these present DO conditions recorded in the tidal Thames from the EA’s Automatic Quality Monitoring Station (AQMS) network.

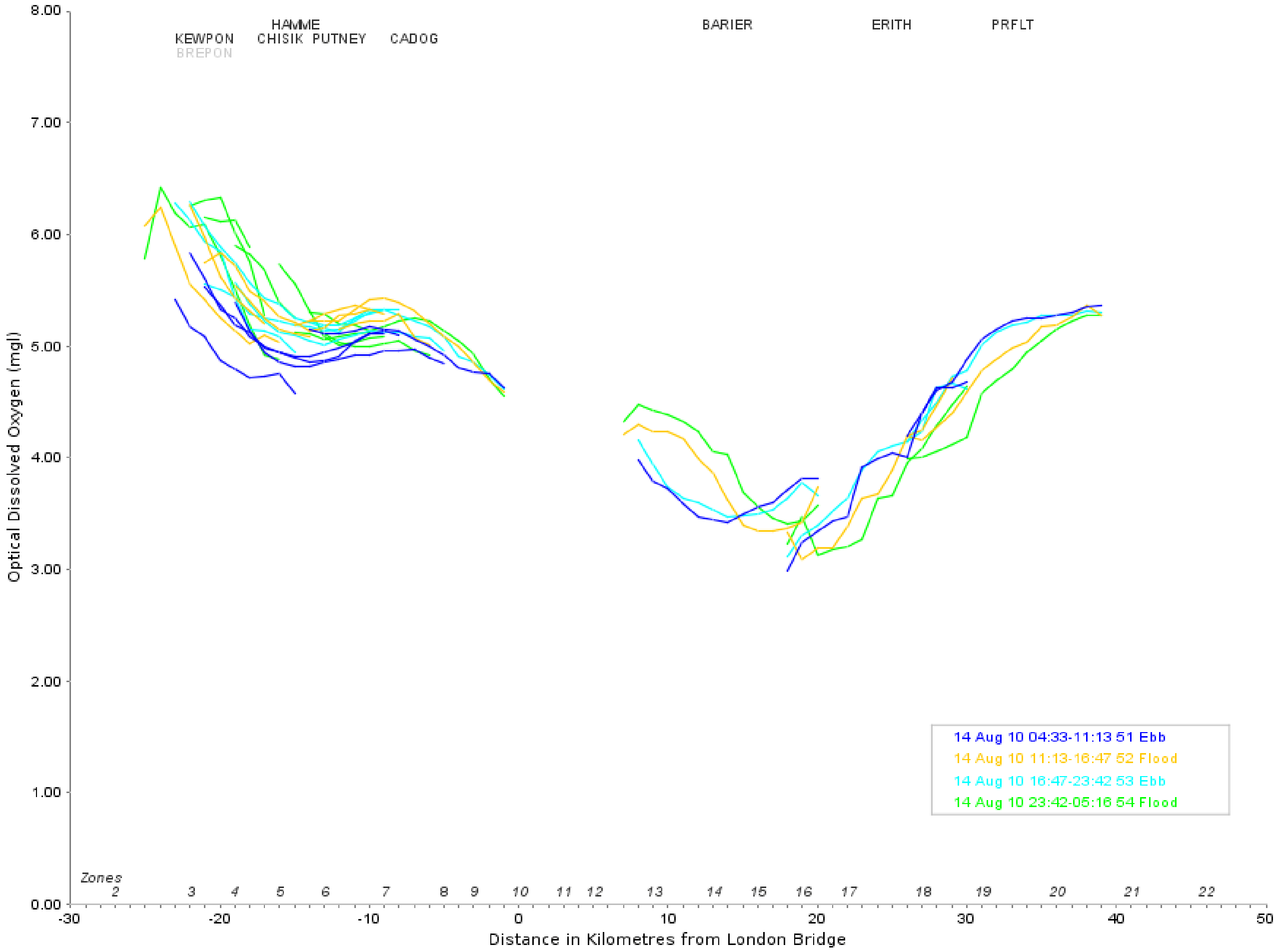
14.4.16 Vol 3 Plate 14.4.1 below shows how the levels of DO at half tide[v] in the tidal Thames varied spatially from Kew in the west to Purfleet in the east

[v] The ‘half tide’ condition is defined as where the volume of water upstream of the location is at its mean value

on the 14th August 2010. These conditions are considered to be 'normal' ie, without a CSO spill event or overflow from the STWs.

14.4.17 Vol 3 Plate 14.4.2 below shows how the levels of DO at half tide in the tidal Thames varied spatially from Kew in the west to Purfleet in the east during spring tide and high fluvial flow conditions on the 7th October 2010. As above, these conditions are considered to be 'normal'.

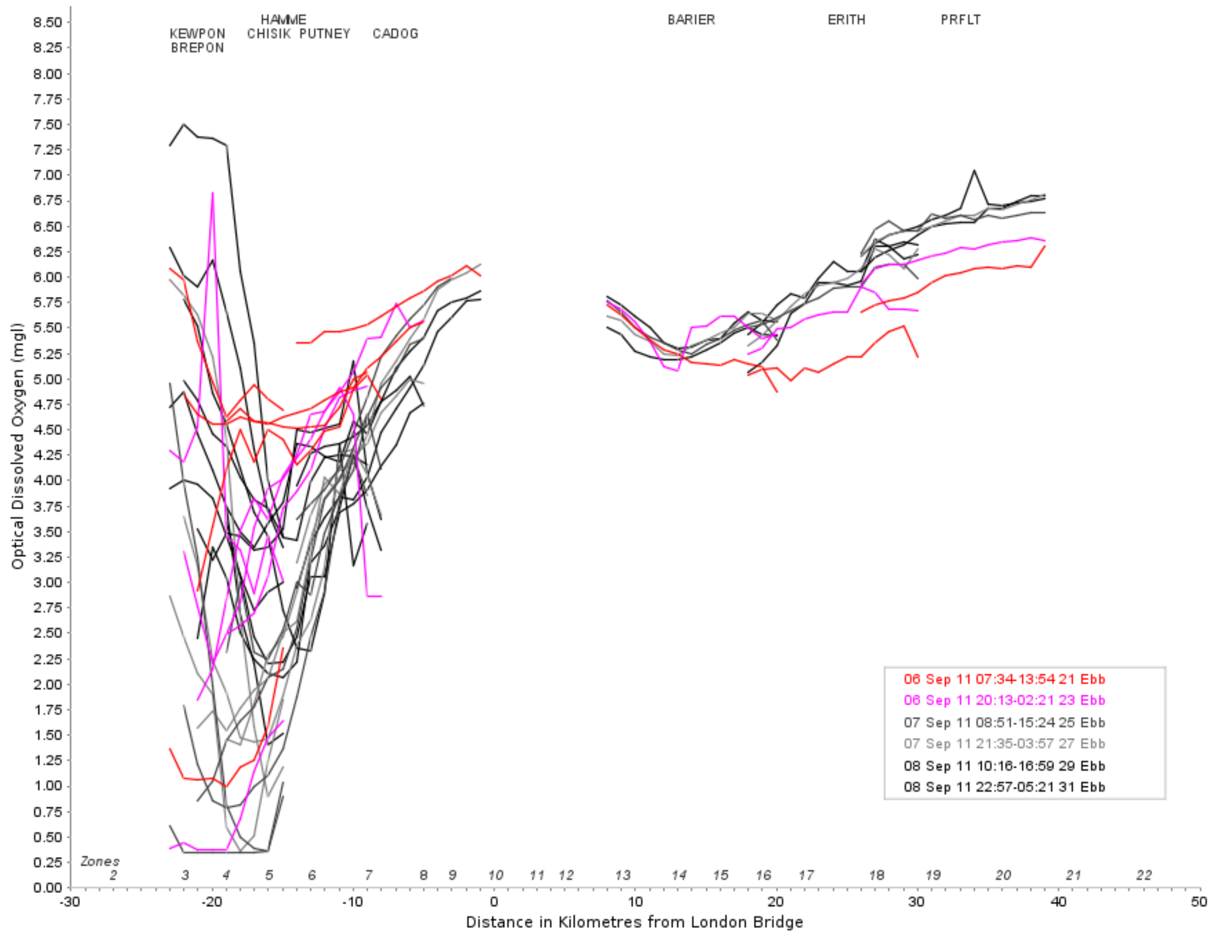
Vol 3 Plate 14.4.1 Surface water – half tide plot showing normal tidal Thames DO levels



14.4.18 In addition to the chronic effects due to the continuous treated effluent discharges described above, the CSO discharges (and STW storm tank spills from Mogden, Crossness, Long Reach and Riverside STWs) that occur intermittently during wet weather can cause acute episodic DO crashes over the space of hours or days, as large volumes of combined sewage are released over a short period of time.

14.4.19 Vol 3 Plate 14.4.2 below demonstrates the effect on DO of a spill event from a number of CSOs and shows how the levels of DO in the tidal Thames vary. Instead of the gradual decrease in DO levels in the lower reaches of the tidal Thames, as observed in the normal (ie, without a CSO spill event) DO plots (shown in Vol 3 Plate 14.4.1 above) a sharp decrease in DO (or sag) is observed at Chiswick, where there are CSO discharges in the vicinity.

Vol 3 Plate 14.4.2 Surface water – half tide plot showing tidal Thames DO levels following a CSO spill event



14.4.20 The DO sag shown in Vol 3 Plate 14.4.2 was caused by spills from a number of CSOs on the 6th and 7th of September 2011; as is often the case with such events, rainfall across the STW catchments caused a number of CSOs to spill concurrently. In this case CSO discharges occurred at Hammersmith Pumping Station CSO, Lots Road Pumping Station CSO, Western Pumping Station CSO and the storm tanks at Mogden STW. The location of these CSOs in the west of the tidal Thames accounts for the event related acute DO crash occurring at Chiswick, which lies in the vicinity of the Hammersmith, Lots Road and Western Pumping Station CSOs.

14.4.21 While the above plot shows the DO crash nearby the CSO discharges, the effects of these episodic DO crashes may be felt for some distance downstream of the CSOs in question depending on the spatial variability of the rainfall event, and due to the movement of river water because of tides.

UWWTD compliance

14.4.22 The 2006 modelled scenario (ie, Scenario 1) results demonstrate the severity of the problem with respect to the impact of the volume, frequency and duration of CSO discharges to the tidal Thames. The effects on DO levels and the subsequent effects on aquatic ecology, the health risk and the volume of sewage derived litter all contribute to the adverse impacts on the environment and are indicative of the failure of the sewage collection and treatment provision, in its current condition, to meet the requirements of the UWWTD (see Vol 3 Appendix L.1 for further details of the requirement of the UWWTD).

Compliance with dissolved oxygen Standards

14.4.23 Although the WFD sets standards for DO, tidal Thames specific DO standards were developed as part of the *TTSS*, based on the requirements of reference fish species reliant on the tidal Thames. These *TTSS* DO standards are supplemental to the WFD standards and are set out in detail in Vol 2 Section 14 and Vol 3 Appendix L.1; a summary is provided below:

a. Threshold 1 – 4mg/l DO: the DO level in the tidal Thames must not fall below 4 mg/l for longer than 29 consecutive tides on more than one occasion per year.

b. Threshold 2 – 3mg/l DO: the tidal Thames DO levels must not fall below 3mg/l for longer than three consecutive tides on more than one occasion every three years

c. Threshold 3 – 2mg/l DO: the tidal Thames DO levels must not fall below 2mg/l for longer than one tide on more than one occasion every five years

d. Threshold 4 – 1.5mg/l DO: the tidal Thames DO levels must not fall below 1.5mg/l for longer than one tide on more than one occasion every ten years.

14.4.24 The *TTSS* DO standards were developed with reference to FIS described by the UPM (Foundation for Water Research, 1998)[9] and as such are compliant with the recommendations of the UKTAG WFD Guidance (UKTAG WFD, 1998)[10].

14.4.25 As explained in Section 14.3 the CTP has been used to demonstrate current levels of compliance with the *TTSS* DO standards. The CTP showed that the current conditions result in:

a. approximately 170 more exceedances of DO threshold 1 than the permissible 41 times in 41 years – this standard is therefore failed under the current conditions

b. approximately 180 more exceedances of DO threshold 2 than the permissible 13 times in 41 years- this standard is therefore failed under the current conditions

c. approximately 91 more exceedances of DO threshold 3 than the permissible 8 times in 41 years - this standard is therefore failed under the current conditions

d. approximately 56 more exceedances of DO threshold 4 than the permissible 4 times in 41 years - this standard is therefore failed under the current conditions.

14.4.26 The results (see also Vol 3 Appendix L.1, Table L.10) show that the current baseline conditions (ie, Scenario 1) fail all of the DO standards that have been developed for the tidal Thames. As a result of low DO levels fish kill events can occur in the tidal Thames, which affects the ability of some key species to survive and can have the effect of reducing the diversity of species present (see Section 5 for detailed ecological assessment).

Construction base case

14.4.27 The Lee Tunnel and the proposed sewage works upgrades would be operational by the time construction of the Thames Tideway Tunnel project commences, as described in Vol 2 Section 14. Improvements in the water quality in the tidal Thames are anticipated as a result of the Lee Tunnel and the sewage works upgrades. Both the base case in Year 1 of construction and Year 1 of operation would therefore be the water quality in tidal Thames with the Lee Tunnel and the sewage works upgrades in place. However, it should be noted that the four *TTSS* DO standards would still be failed as the majority of all CSOs (with the exception of the Abbey Mills CSO) will still be regularly discharging to the tidal Thames. For example, Hammersmith Pumping Station CSO is predicted to continue discharging approximately 2,350,000 m^3 over 54 spill events under Scenario 2 (see Vol 3 Appendix L.1 Table L.6 for spill frequencies for all CSOs).

14.4.28 For the assessment of construction impacts, the effects have been assessed against a 2021 modelled simulation (ie, Scenario 2) that includes the impact of predicted population increases and the effect of the proposed sewage works upgrades and the operation of the Lee Tunnel. This assumption is considered reasonable as substantial changes in water quality are considered unlikely between 2016 and 2021.

14.4.29 The construction base case has considered the other developments that are scheduled to be complete and in operation by Year 1 of construction (presented in Vol 3 Appendix A.1). The developments in Vol 3 Appendix A.1 would not result in additional surface water receptors (ie, waterbodies) and are considered unlikely to result in changes in water quality as the majority of these developments are remote from the tidal Thames. The base case would therefore not change from that outlined above.

14.4.30 The projects listed Vol 3 Appendix A.1 that would be under construction during Year 1 of construction of have been considered in the cumulative effects assessment.

14.4.31 The assessment area for the assessment of effects of construction activities from the project are the two sections of the river, namely the Thames Upper and Middle waterbodies listed above in Vol 3 Table 14.4.1.

Operational base case

14.4.32 The assessment year for operational effects is Year 1 of operation of the Thames Tideway Tunnel project. As with the construction assessment, the operational assessment also relies on modelled water quality data which uses population projections for 2021.

14.4.33 As noted above, the operational base case would be the same as the construction base case ie, the water quality in the tidal Thames with the

Lee Tunnel and sewage works upgrades in place. The operational base case has considered the other developments that are scheduled to be complete and in operation by Year 1 of operation (presented in Vol 3 Appendix A.1). The developments in Vol 3 Appendix A.1 would not result in additional surface water receptors (ie, waterbodies) and are considered unlikely to result in changes in water quality as the majority of these developments are remote from the tidal Thames. The base case would therefore not change from that outlined above.

14.4.34 No other major developments have been identified that would be under construction during Year 1 of operation of the Thames Tideway Tunnel project and so a cumulative effects assessment has not been undertaken.

14.4.35 The operational assessment uses the same assessment area identified above for the construction assessment.

Base case: CSO characterisation

14.4.36 The base case model scenario (Scenario 2) includes predicted increases in population, and so increases in discharge volume, frequency and spill duration for the majority of individual CSOs are predicted. However, there would be an overall reduction in the total volume discharged owing to the increase capture of flow at the improved STWs and operation of the Lee Tunnel.

14.4.37 The Beckton STW expansion and the Lee Tunnel will collect discharges from the Abbey Mills CSO which currently constitutes over 50% of the total volume discharged to the River Lee and tidal Thames annually and transfer them to Beckton STW for treatment or spill to the river at the new Tideway CSO when the Lee Tunnel is full. Catchment modelling results for the base case show that the predicted volume of CSO discharges entering the river annually would be 17,600,000m^3 (see Vol 3 Table 14.4.4 below). This represents a 56% reduction in total volume from the current conditions of 39,600,000 m^3 (see Vol 3 Table 14.4.2). The locations at which this volume would be discharged would vary spatially, as shown in the Vol 3 Table 14.4.4. A reduction in spills from the Greenwich Pumping Station CSO would also result from the upgrade at Crossness STW, as noted below in Vol 3 Table 14.4.4. See Section 14 in Vols 4 to 27 for predicted site specific volumes discharged per annum.

14.4.38 The sewage works upgrades and the Lee Tunnel represent a major step in improving the condition of the tidal Thames, but are only one part of the overall solution required to address the problem. DO standards would still be failed under Scenario 2 (see para. 14.4.48 below). However most CSOs along the tidal Thames continue to discharge frequently and with higher volumes.

Vol 3 Table 14.4.4 Surface water – annual spill volumes in the Typical Year for the base case (Scenario 2)

Location	Spill volume (m3)	% change from current conditions	Notes
Teddington to Putney Bridge	2,640,000	0.4%	The change is relatively minor because of improvements to Acton Storm Tanks operation which would form part of the agreement for constructing the Acton shaft at Acton storm tank site. This off sets the net increase in population
Putney Bridge to London Bridge	6,780,000	+11	As a result of population increase
London Bridge to Greenwich	7,470,000	-33	As a result of improvements to Crossness STW which also controls the Greenwich pumping station spill to the river (part of the overall London Tideway Improvements)
Greenwich to Henley Road	14,000	-99.9	As a result of the Lee Tunnel
Henley Road to Crossness	659,000	The Beckton STW expansion and the Lee Tunnel will capture and treat the majority of existing CSO spills from Abbey Mills. However, some events will exceed the storage capacity of the Lee Tunnel and will be discharged to the tidal Thames near Beckton STW at the Tideway CSO. This would result in an increase in spills between Henley Road and Beckton. Residual spills at the Tideway CSO would occur on average three times in the Typical Year (53 less than currently occurs at Abbey Mills).	
Total	**17,600,000**	**-55%**	

14.4.39 The modelling shows that in Year 1 of operation (assessed using 2021 modelled assumptions ie, Scenario 2), the maximum hours of discharges from the CSOs will be 698 hours per annum during the Typical Year; 175 hours (20%) less than current conditions. With the STW upgrades and the Lee Tunnel, there will be a 55% reduction in the total volume of combined sewage entering the tidal Thames compared to the current base line (using 2006 modelled conditions). However, the volumes and spill frequencies of combined sewage discharge in the tidal Thames would remain large, as the majority of the CSOs would show an anticipated increase in spill volumes and frequencies due to increased population. The exception to this would be the Abbey Mills CSO, Greenwich pumping station CSO and Acton storm tanks CSO which would show a reduction due to improved operations of the storm tanks.

Vol 3 Table 14.4.5 Surface water – Annual spill volumes in the Typical Year: comparison

Location	Current baseline conditions (Scenario 1) (m^3)	Base case (Scenario 2) (m^3)
Teddington to Putney Bridge	2,630,000	2,640,000
Putney Bridge to London Bridge	6,100,000	6,780,000
London Bridge to Greenwich	11,200,000	7,470,000
Greenwich to Henley Road (including Abbey Mills)	19,400,000	14,000
Henley Road to Crossness	308, 000	659,000
TOTAL	**39,600,000**	**17,600,000**

14.4.40 The following sections consider the operational base case for three of the key variables which are addressed by the Thames Tideway Tunnel project:

a. exposure to pathogens

b. sewage-derived litter

c. dissolved oxygen.

Exposure to pathogens

14.4.41 The changes in CSO characterisation have been used to determine the risk of exposure to pathogens for recreational users of the tidal Thames for the operational base case (see Vol 3 Table 14.4.6 below).

Vol 3 Table 14.4.6 Surface water – indicative number of risk days base case

Location	CSO with greatest spill frequency	Number of spills	Indicative risk days (maximum)	Change from current baseline (highest risk days)
Teddington to Putney Bridge	Hammersmith Pumping Station	54	216	+6%

Location	CSO with greatest spill frequency	Number of spills	Indicative risk days (maximum)	Change from current baseline (highest risk days)
Putney Bridge to London Bridge	Falconbrook and Lots Road Pumping Station	42	168	0%
London Bridge to Greenwich	Deptford Storm Relief	39	156	-24%
Greenwich to Henley Road	Isle of Dogs Pumping Station (major effect is from Abbey Mills CSO control)	7	28	-87%
Henley Road to Crossness	Tideway CSO and Crossness Storm tanks	3	12	-40%

Note: Figures are at different locations in the tidal Thames in the Typical Year (2021 modelled scenario)

14.4.42 These results demonstrate that there would be a slight increase in exposure risk in the tidal Thames sections from Teddington to London Bridge when compared with the modelled current baseline conditions. The Lee Tunnel project and sewage works upgrades would result in a reduced risk of exposure of approximately:

a. 24% between London Bridge and Greenwich

b. 87% between Greenwich and Henley Road

c. 40% between Henley Road and Beckton.

Sewage derived litter

14.4.43 Based on the percentage reduction in overall volumes discharged (55%) when compared to the current baseline, there would be a reduction in sewage derived litter of approximately 5,500t under the operational base case although 4,500t of litter would still enter the tidal Thames annually.

UWWTD compliance

14.4.44 The 2021 scenario base case modelling demonstrates that although there will be an improvement in annual discharge volume and STW effluent quality as a result of the Lee Tunnel and sewage works upgrades, the volume, frequency and duration of CSO discharges to the tidal Thames are in excess of those acceptable to meet the requirements of the UWWTD.

14.4.45 The effects on DO levels and the subsequent effects on aquatic ecology, the health risk to river users and the volume of sewage derived litter all contribute to the adverse impacts on the environment and are indicative of the failure of the sewage collection and treatment provision to meet the requirements of the UWWTD under the base case.

Compliance with dissolved oxygen standards

14.4.46 Simulation of the 242 CTP summer events using the QUESTS model show that for the base case there would be:

a. approximately 34 more exceedances of DO threshold 1 than the permissible 41 times in 41 years; the tidal Thames would fail this standard under the base case conditions

b. approximately 27 more exceedances of DO threshold 2 than the permissible 13 times in 41 years; the tidal Thames would fail this standard under the base case conditions

c. approximately four more exceedances of DO threshold 3 than the permissible 8 times in 41 years; the tidal Thames would fail this standard under the base case conditions

d. approximately three more exceedances of DO threshold 4 than the permissible 4 times in 41 years; the tidal Thames would fail this standard under the base case conditions.

14.4.47 The model demonstrates that the Lee Tunnel project and the proposed sewage works upgrades would result in a reduction in the number of exceedances of each of the thresholds but the DO standards would still be failed.

WFD compliance

14.4.48 The Thames Upper waterbody will be unaffected by the Lee Tunnel project and sewage works upgrades (with the exception of Mogden), as water quality benefits from the projects on the tidal Thames will largely occur downstream of London Bridge. Improvements in water quality in the Thames Upper waterbody will result from the Mogden STW upgrades. However the volume, frequency and duration of the CSO discharges within this waterbody will increase from current baseline conditions to the base case due to predicted population increases. The operational base case conditions for the Thames Upper would therefore remain as 'moderate potential' as defined in the Thames RBMP.

14.4.49 Improvements will be realised in the Thames Middle waterbody as a result of the operation to improve treatment works and the Lee Tunnel, although these improvements will not be sufficient to allow the Thames Middle waterbody to reach future 'good potential' with regards to WFD DO objectives. The Lee Tunnel will contribute towards the attainment of WFD water quality objectives in the lower River Lee and subsequently on the Thames Middle waterbody in conjunction with improvement works at Beckton, Crossness, Riverside and Long Reach STWs. However, spills from CSOs in the Thames Middle waterbody would continue to restrict the attainment of 'good potential' and the base case condition for the Thames

Middle would therefore remain as ‘moderate potential’ as defined in the Thames RBMP.

14.5 Construction effects assessment

14.5.1 The majority of the construction effects on surface water would be local to each of the construction sites and have therefore been assessed in the site-specific Vols 4 to 27 Section 14. However, there are also potential project-wide impacts that could result from the construction phase of the project and these are discussed below.

Construction impacts

Sediment mobilisation

14.5.2 As noted in Section 14.2, the following sources of potential release of sediment into the tidal Thames have been identified from the proposed construction works:

a. dredging

b. piling (including cofferdam construction)

c. campshed construction

d. losses of material during transfer to barges

e. barge operation

f. scour.

14.5.3 Dredging is proposed at the Blackfriars Bridge Foreshore, Carnwath Road Riverside and Kirtling Street sites, where it is assumed that a proportion of the dredged material would be lost to the water column. Assuming a 5% loss of material from the proposed backhoe dredging method, the proposed 6,000m^3 dredge could release approximately 1,000t[vi] of fine sediment into the river from the three sites combined.

14.5.4 Piling would be needed for all foreshore sites and may disturb bed sediments in the immediate vicinity of the site, through a reduction in the compaction and strength of the bed. An estimated 900t of fine sediment could be released by the proposed piling at all sites combined.

14.5.5 Campshed construction would be required at a number of the foreshore sites and as with piling this may disturb bed sediments in the immediate vicinity of the site. Fine sediment released from campshed construction is likely to be minimal, however, as a precautionary approach, it is estimated that 1,600t would be released into suspension at all sites combined.

14.5.6 During transfer of excavated material to barges for removal and of fill material from barges for construction, losses of material to the river may occur. It is estimated that these losses could be up to 0.5% although actual loss rates are likely to be substantially lower. An estimated

[vi] An assessment of the potential sediment losses anticipated from construction activities within the foreshore is provided in the *Habitats regulation assessment.*

maximum 4,000t of sediment could therefore be lost to the river during material transfer from all sites combined during the construction period.

14.5.7 The river would be used to transport excavated materials from the Thames Tideway Tunnel project and the passage of barges and the tugs used to power them may result in the disturbance of material from the river bed. Downstream of Westminster Bridge, barges make up a relatively small proportion of the total vessel traffic on the river and so the additional barge traffic associated with the proposed development would not have a substantial impact on the mobilisation of fine sediment. Upstream of Westminster Bridge, and due to the restriction on vessel movements imposed by the size of the bridge, it is estimated that there would be an increase of approximately 10-20% of the total vessel movements, which could result in sediment redistribution and release of fine material. The likely locations for the sediment disturbance are in the proximity of the main tunnel construction sites (ie, Chambers Wharf, Carnwath Road Riverside and Kirtling Street), where barge movements would be greatest. Sediment modelling[vi] suggests 1,200t of fine sediment may be released into the water from barging operations at all sites combined during the construction period.

14.5.8 A number of scour processes are predicted as a result of the proposed development (see Vol 3 Appendix L.3), with contraction scour (scour across the bed of the river channel due to increased flow velocities caused by channel narrowing from in-river structures) predicted for the temporary structures. Combining the modelled scour depth with the modelled area of influence results in an estimated 5,300t of fine sediment which could be released into the water column by contraction scour at all sites combined. This volume is based on the assumption that there would be no local scour protection measures for contraction scour during the construction period.

Vol 3 Table 14.5.1 Surface water – estimated sediment releases from construction works

Sediment source	Estimated sediment quantity (t)
Dredging	1,000
Piling	900
Campshed construction	1,600
Losses of material during transfer to barges	4,000
Barge operations	1,200
Scour	5,900
Total	**14,600**

14.5.9 In summary, it is estimated that a total of 14,600t of fine sediment could be released during construction from all of the identified sources above.

Foul drainage

14.5.10 It is estimated that the project could create approximately 3,200 construction jobs. This would create additional wastewater volumes which could result in an increase in loading of the sewage system. A standard assumption based on the 2001 census (Office of National Statistics, 2001)[11] is that a proportion of jobs created by the project would go to people living outside the Greater London area; this is assumed to be approximately 13% or 553 workers based on a maximum of 4,250 (see Vol 3 Section 10 Socio-economics for details of employment figures for the project).

14.5.11 It can therefore be assumed that only foul drainage from 553 construction workers would be additional loading to the Thames Water foul sewer network in London. Based on a figure of 60 litres per head per day for construction workers on sites without a canteen (British Water, 2009)[12] this would represent an additional flow of 33,180 litres or 33.8m^3 per day. It is considered that such a small volume (representing 0.003% of the 2021 base case modelled average DWF flow from Beckton STW of 1,336,000m^3 per day) would have a negligible effect on the sewer network of London and is not considered further within this assessment.

Construction effects

14.5.12 The potential surface water impacts identified above as a result of the proposed construction works have been assessed for their likely effects on WFD objective compliance, compliance with other legislation and effects on other users of the surface waters. The significance of these effects has then been assessed based on the magnitude of the impacts as described in Vol 2 Section 14.5.

Sediment mobilisation and scour

14.5.13 In comparison to the existing sediment levels within the tidal Thames, which have been estimated to reach a peak of 4,000kg per second or more than 40,000t in each tide (HR Wallingford, 2006)[13]. In this context the release of 14,600t over the six year construction period would represent a small additional input of less than 10t per tide on average, which is an increase of 0.025%. The potential effect of the release of sediment from the proposed development is therefore considered to be **negligible**.

14.5.14 The construction of in-river structures at some foreshore sites would affect the river regime with the potential that localised changes in flow velocity could cause scour of the river bed and foreshore, or deposition of sediments. Any potential scour development during construction would be monitored and if relevant trigger levels are reached, appropriate protection measures would be provided. Further details are provided in *Scour Monitoring and Mitigation Strategy* (Vol 3 Appendix L.4). The potential effect of scour from the proposed development is therefore considered to be **negligible**.

Deposition

14.5.15 Local deposition of sediments may occur around the temporary works in the river, including cofferdams and jetties. This has been assessed within the site specific assessments and has not been assessed on a Project-wide basis.

14.6 Operational effects assessment

Operational impacts

14.6.1 In order to assess the significance of the operational impacts that would result from the project a modelled simulation has been used that includes predicted population increases 2021, the proposed sewage works upgrades, the operation of the Lee Tunnel and the operation of the Thames Tideway Tunnel project (see para. 14.3.7). This is also known as the development case.

Sediment mobilisation

14.6.2 Scour has been identified as a source of potential release of sediment into the tidal Thames from the permanent structures within the foreshore (see Vol 3 Appendix L.3). A number of scour processes are predicted as a result of the proposed development, with contraction scour (scour across the bed of the river channel due to increased flow velocities caused by channel narrowing from in-river structures) predicted for permanent structures. However, as the permanent structures would be smaller than the temporary works, the resultant scour would also be less. When compared to the background sediment levels within the tidal Thames, estimated to currently reach a peak of 40,000t in each tide, the additional sediment from scour from the permanent works would be negligible.

Permanent land take and morphological changes

14.6.3 In order to accommodate the permanent works in the foreshore of the tidal Thames, construction of permanent structures within the river channel would be required. At some sites the channel would be more constricted than at present and together with the new profile, this would be likely to lead to changes in flows (velocities, directions) and could lead to changes in scour and deposition of sediments.

14.6.4 The permanent structures could affect the river regime with the potential that localised increases in flow velocity cause scour of the river bed and foreshore and could result in the mobilisation of suspended solids. The approach to scour protection for the permanent works is described in the *Engineering Design Statement* and scour is not considered further with the assessment. Impacts on channel morphology from permanent land take can have an effect on ecological receptors, by changing habitat availability. This effect is assessed in Section 5 of this volume.

Development case: CSO characterisation

14.6.5 The catchment model results have been used to characterise the CSO conditions in Year 1 of operation of the Thames Tideway Tunnel project (2023) (assessed using 2021 modelled assumptions ie, Scenario 3). The results are summarised in Vol 3 Table 14.6.1, Vol 3 Table 14.6.2 and Vol 3 Table 14.6.3 below. The results demonstrate how the project would reduce the volume, frequency and duration of CSO discharges during rainfall in the Typical Year when compared to the base case.

14.6.6 The catchment modelling results show that in the Typical Year the Thames Tideway Tunnel project would:

a. reduce the total volume of combined sewage entering the river by 87%[vii], (15,250,000m^3 less), from 17,600,000m^3 to 2,350,000m^3, when compared to the base case

b. reduce the maximum number of CSO spill events from 54 to 7 across the tidal Thames when compared to the base case. For the 34 CSOs targeted by the Thames Tideway Tunnel project, this would be reduced to no more than 4 CSO spills in the Typical Year.

c. reduce the total length of time that spills would occur from all of the CSOs to the tidal Thames from 698 hours to 36 hours, when compared to the base case.

Vol 3 Table 14.6.1 Surface water – Annual spill volumes in the Typical Year for the development case

Location	Base case (Scenario 2) (m^3)	Development case (Scenario 3) (m^3)	% change from base case
Teddington to Putney Bridge	2,640,000	108,000	-96
Putney Bridge to London Bridge	6,780,000	538,000	-92
London Bridge to Greenwich	7,470,000	951,000	-87
Greenwich to Henley Road	14,000	14,000	0
Henley Road to Crossness	659,000	735,000	+12
Total	**17,600,000**	**2,350,000**	**-87**

14.6.7 CSO spill volumes would increase in the Henley Road to Beckton stretch of the tidal Thames. This is due to increased spills from the Tideway CSO at Beckton STW as a result of the transfer of intercepted CSO flows via the London Tideway Tunnels (Lee Tunnel and Thames Tideway Tunnel project).

[vii] When compared with the current baseline conditions of 39.6 million m^3 annual CSO discharges in the Typical Year, this is a 94% capture of annual discharges.

14.6.8 However Vol 3 Table 14.6.2 below demonstrates that the frequency of spill from the Tideway CSO in this stretch of the river would not change, only the volume.

Vol 3 Table 14.6.2 Surface water – Annual spill frequency in the Typical Year for the development case

Location	Base case (Scenario 2) - maximum spill frequency per annum (Typical Year)	Development case (Scenario 3) - maximum spill frequency per annum (Typical Year)	Change from base case	% change from base case
Teddington to Putney Bridge	54	3	-51	-94
Putney Bridge to London Bridge	42	6	-36	-86
London Bridge to Greenwich	39	4	-35	-90
Greenwich to Henley Road	7	7	0	0
Henley Road to Crossness	3	3	0	0
Maximum spill frequency	**54**	**7***	**-47**	**-87%**

*Note: * 7 spills from all CSOs along the tidal Thames. For the 34 targeted unsatisfactory CSOs controlled by the Thames Tideway Tunnel project, this would be reduced to no more than 4 spills in the Typical Year.*

Vol 3 Table 14.6.3 Surface water – Annual spill duration in the Typical Year for the development case

Location	Base case (Scenario 2) - maximum CSO spill duration (hours)	Development case (Scenario 3) - maximum CSO spill duration (hours)	Change from base case	% change from base case
Teddington to Putney Bridge	698	16	--682	-98%
Putney Bridge to London Bridge	407	31	-379	-92%
London Bridge to Greenwich	342	36	-307	-89%

Location	Base case (Scenario 2) - maximum CSO spill duration (hours)	Development case (Scenario 3) - maximum CSO spill duration (hours)	Change from base case	% change from base case
Greenwich to Henley Road	11	11	0	0%
Henley Road to Crossness	18	21	+3	+11%
Maximum duration of spills	**698**	**36**	**-662**	**-95%**

14.6.9 As with the CSO spill volumes discussed above, the CSO spill duration would increase in the Henley Road to Crossness stretch of the tidal Thames due to increased spill duration from the Tideway CSO at Beckton.

Exposure to pathogens

14.6.10 The changes in the risk of exposure to pathogens for recreational users of the tidal Thames have been determined using the CSO characterisation for the development case as shown in Vol 3 Table 14.6.4 below.

Vol 3 Table 14.6.4 Surface water – number of risk days for development case

Location	Base case (Scenario 2) - spills per annum	Base case (Scenario 2) - indicative risk days (maximum)	Development case (Scenario 3) - spills per annum	Development case (Scenario 3) - indicative risk days	% change from base case
Teddington to Putney Bridge	54	216	3	12	94
Putney Bridge to London Bridge	42	168	6	24	86
London Bridge to Greenwich	39	156	4	16	90
Greenwich to Henley Road	7	28	7	28	No change
Henley Road to Crossness	3	12	3	12	No change

Note: Figures are indicative for the Typical Year

14.6.11 The results demonstrate that the Thames Tideway Tunnel project would result in a substantial reduction of the risk of exposure to pathogens in those sections of the tidal Thames between Teddington and Greenwich.

Sewage derived litter

14.6.12 Based on the percentage reduction in overall volumes discharged (87%) compared to the base case, the development case would result in an annual reduction in sewage derived litter entering the tidal Thames of approximately 4,000t (leaving a residual 600t in a Typical Year).

Dissolved oxygen

14.6.13 As explained in Section 14.3, in order to determine the likely impact of the Thames Tideway Tunnel project on DO, the QUESTS model has been simulated for selected 242 CTP summer events selected from 1970 to 2010 (41 years) The results have been analysed to determine whether the development case could achieve compliance with the DO thresholds set for the tidal Thames during the *TTSS*.

14.6.14 The QUESTS development case (Scenario 3) results show that in Year 1 of operation there would be:

a. 21 exceedances of DO threshold 1, compared to the permissible 41 times in 41 years; so the tidal Thames would pass this standard.

b. 4 exceedances of DO threshold 2 compared to the permissible 13 times in 41 years; so the tidal Thames would pass this standard.

c. one exceedance of DO threshold 3 compared to the permissible eight times in 41 years; so the tidal Thames would pass this standard.

d. one exceedance of DO threshold 4 compared to the permissible four times in 41 years; so the tidal Thames would pass this standard.

14.6.15 The QUESTS model results for all modelled scenarios show that only when the Thames Tideway Tunnel project is included are all of the four *TTSS* DO standards passed, as shown below in Vol 3 Table 14.6.5.

Vol 3 Table 14.6.5 Surface water – DO standard compliance

DO Standard	1	2	3	4
DO value and tidal duration threshold	**4 mg/l for 29 tides***	**3 mg/l for 3 tides**	**2 mg/l for 1 tide**	**1.5 mg/l for 1 tide**
Allowable exceedances in 41 years (frequency)	**41 (1:1yr)**	**13 (1:3yr)**	**8 (1:5yr)**	**4 (1:10yr)**
Scenario	Simulated maximum number of exceedances of DO thresholds			
Existing System	211	193	99	60
	Fails**	Fails	Fails	Fails
STWs Improvement and Lee Tunnel	75	40	12	7
	Fails	Fails	Fails	Fails
STWs Improvements,	21	4	1	1

DO Standard	1	2	3	4
Lee Tunnel and Thames Tideway Tunnel project	Compliant***	Compliant	Compliant	Compliant

** A tide is a single ebb or flood.*
*** Failure of the standard occurs when the predicted number of exceedances at a single reach exceeds the allowable number of exceedances.*
****Although there are exceedances of the threshold (that is the DO is less than the DO value for the tidal duration in the standard) the number of exceedances over the 41 year is less than the allowable number (the frequency of occurrence criteria) is met so the result is compliant.*

Operational effects

Reduction in CSO spills

UWWTD compliance

14.6.16 The modelling undertaken for the development case demonstrates a major reduction in CSO spill frequency with a reduction from over 50 spills per year in the operational base case to seven spills per year (in the Typical Year). This would result in an 87% reduction in the volume of combined sewage entering the tidal Thames. This would allow compliance with the UWWTD, resulting in a **major beneficial** effect.

Compliance with dissolved oxygen standards and the WFD

14.6.17 While the *TTSS* DO standards are different from the WFD DO standard of an annual 5-percentile DO compliance depending on salinity, it is considered that by achieving the four *TTSS* DO standards, the project would contribute towards meeting all four of the WFD environment objectives for surface water. These are set out below:

a. WFD objective 1: Prevent deterioration of the status of all bodies of surface water.

b. WFD objective 2: Protect, enhance and restore all bodies of surface water, with the aim of achieving good surface water status by 2015 (or 2027 where measures will take longer to implement[viii]).

c. WFD objective 3: Protect and enhance all artificial and heavily modified bodies of water, with the aim of achieving good ecological potential and good surface water chemical status by 2015 (or 2027 where measures will take longer to implement).

d. WFD objective 4: Reduce pollution from priority substances and cease or phase out emissions, discharges and losses of priority hazardous substances.

14.6.18 WFD objectives 2 and 3 have the aim of achieving good potential for a waterbody. While the Thames Tideway Tunnel project does not result in good status being achieved, it represents an important step towards it by moving an additional 13km of the tidal Thames to ‘good potential’ from ‘moderate potential’ (see Vol 3 Appendix L.1 and Vol 3 Appendix L.2). For

[viii] If the measures proposed by the RBMP to achieve good status (or potential) could not achieve the target by 2015 due to disproportionate cost or technical infeasibility, as target of achieving good status (or potential) by 2027 is set.

the section of the tidal Thames which would remain at moderate potential, there would be up to 1 mg/l improvement in DO levels as a result of the Thames Tideway Tunnel project. The Thames Tideway Tunnel project would assist the Thames Upper and Thames Middle waterbodies in reaching 'good potential' in combination with other measures proposed for the waterbody (see RBMP (EA, 2009)[14]). Without the Thames Tideway Tunnel project, the *TTSS* DO standards would be failed and reaching WFD 'good potential' by 2027 would be hindered. Therefore, this would be a **major beneficial** effect.

Exposure to pathogens

14.6.19 The associated reduction in exposure to pathogens would greatly improve the conditions for recreational users of the tidal Thames, with a reduced risk of exposure. This is considered to be a **moderate beneficial** effect. This effect is only considered as a moderate beneficial effect (rather than a major beneficial) as the beneficial effects of the project are unlikely to contribute to moving the waterbodies to a higher WFD status as pathogens are not a component of the WFD status, despite the substantial improvements which would occur.

Sewage derived litter

14.6.20 The reduction in sewage litter discharge would improve the aesthetic quality of the tidal Thames, improving conditions for recreational users. This is considered to be a **moderate beneficial** effect. This effect is only considered as a moderate beneficial effect (rather than a major beneficial) as the beneficial effects of the project are unlikely to contribute to moving the waterbodies to a higher WFD status as sewage derived litter is not a component of the WFD status, despite the substantial improvements which would occur

Permanent land take and morphological changes

14.6.21 The permanent structures proposed in the tidal Thames have been designed and engineered to minimise the impediment of flow and although some changes to flows are likely, the changes are unlikely to lead to further substantive change of the morphological condition of the channel which is already modified by flood defences and channel dredging. In addition, the changes in flow are unlikely to lead to areas of slack 'dead' water around the permanent structures. WFD objectives one and three are not considered to be affected by this change, and hence the effect is considered to be **minor adverse**.

14.6.22 Impacts on channel morphology can also have an effect on ecological receptors, by changing habitat availability. This effect is assessed in Section 5 of this volume.

Climate change

Base case: climate change

CSO characterisation

14.6.23 Climate change predictions[ix] suggest warmer, drier summer months and warmer, wetter winter months, although the total annual rainfall over the catchment will be similar to today. Change in temperature will affect the future water quality in the tidal Thames. Summer river flows in the River Thames (ie, the non-tidal sections upstream of Teddington Weir) are projected to be lower and river water temperature is projected to increase by 1.5 to 2.0^{o}C for the 2050s and 2.5 to 3.0^{o}C for the 2080s.

14.6.24 As explained in Section 14.4, to describe the 2080 base case without the Thames Tideway Tunnel project, a simulation has been used (scenario 4). This uses 2080 conditions including population estimates and assumes that only the Lee Tunnel and proposed sewage works upgrades are in place. Modelling shows that in the Typical Year for the climate change base case scenario there would be an increase in the volume of CSO discharges entering the river compared to the base case (Vol 3 Table 14.6.6). There would also be an increase in the maximum duration of spills and a decrease in the frequency (Vol 3 Table 14.6.6).

Compliance with dissolved oxygen standards

14.6.25 Modelling shows that for the climate change base case there would be:

a. approximately 121 more exceedances of DO threshold 1 than the permissible 41 times in 41 years; the tidal Thames would fail this standard under the climate change base case conditions

b. approximately 62 more exceedances of DO threshold 2 than the permissible 13 times in 41 years; the tidal Thames would fail this standard under the climate change base case conditions

c. approximately 17 more exceedances of DO threshold 3 than the permissible 8 times in 41 years; the tidal Thames would fail this standard under the climate change base case conditions

d. approximately nine more exceedances of DO threshold 4 than the permissible 4 times in 41 years; the tidal Thames would fail this standard under the climate change base case conditions.

[ix] The best available climate projections for the UK are the UKCP09 projections, based upon the Met Office Hadley Centre climate models. UKCP09 provides an estimate of the range of model-related uncertainties in the future projections, along with high, medium and low emissions scenarios. The modelling has been undertaken using the 10, 50 and 90 percentiles to explore the implications of these uncertainties for 2050s (2040 to 2069) and 2080s (2070 to 2099) time horizons.

Vol 3 Table 14.6.6 Surface water –Typical Year climate change base case comparison

Location	Annual spill volumes (m^3)		Maximum annual spill frequency		Annual spill duration (hours)	
	base case (Scenario 2)	**2080 base case (Scenario 4)**	**base case (Scenario 2)**	**2080 base case (Scenario 4)**	**base case (Scenario 2)**	**2080 base case (Scenario 4)**
Teddington to Putney Bridge	2,640,000	2,950,000	54	52	698	727
Putney Bridge to London Bridge	6,780,000	7,550,000	42	48	407	98
London Bridge to Greenwich	7,470,000	9,010,000	39	48	342	396
Greenwich to Henley Road	14,000	13,000	7	7	11	10
Henley Road to Beckton / Crossness	659,000	1,270,000	3	5	18	30
Total/Maximum	**17,600,000**	**20,800,000**	**54**	**52**	**698**	**727**

Development case: climate change

14.6.26 Modelled Scenario 5, described in Section14.3, uses 2080 conditions including population predictions. It also assumes the Lee Tunnel, proposed sewage works upgrades and Thames Tideway Tunnel project are all in place and remain unchanged. Vol 3 Table 14.6.7, Vol 3 Table 14.6.8 and Vol 3 Table 14.6.9 show the effects of these changes in climate on the CSO spill volume, frequency and duration compared against a modelled scenario without the Thames Tideway Tunnel project (Scenario 4).

Vol 3 Table 14.6.7 Surface water – Annual spill volumes in the Typical Year climate change comparison

Location	2080s base case (Scenario 4) (m^3)	2080s development case (Scenario 5) (m^3)	Change from 2080s base case	% change from 2080s base case
Teddington to Putney Bridge	2,950,000	244,000	-2,706,000	-92%
Putney Bridge to London Bridge	7,550,000	852,000	-6,698,000	-89%
London Bridge to Greenwich	9,010,000	1,310,000	-7,700,000	-85%
Greenwich to Henley Road	13,000	42,000	The development case shows an increase in the spill volume in this reach. This is because in the base case, no spills occur from the Abbey Mills pumping station CSO as flows are diverted to Beckton STW and occur at the Tideway CSO. In the development case, under exceptional cases (one every ten years) spills would occur from the Abbey Mills pumping station CSO. With 2080 rainfall data, there is now one event during the Typical Year that would cause the Abbey Mills pumping station CSO to spill 29,000m^3 with the Thames Tideway Tunnel project in operation, which results in an increase in spills of 223%.	
Henley Road to Beckton / Crossness	1,270,000	1,035,000	-235,000	-19%

Location	2080s base case (Scenario 4) (m^3)	2080s development case (Scenario 5) (m^3)	Change from 2080s base case	% change from 2080s base case
Total	**20,800,000**	**3,480,000**	-17,320,000	**-83%**

Vol 3 Table 14.6.8 Surface water – Annual spill frequency in the Typical Year climate change case

Location	2080s base case (Scenario 4) - maximum spill frequency per annum	2080s development case (Scenario 5)- maximum spill frequency per annum	Change from 2080s base case	% change from 2080s base case
Teddington to Putney Bridge	52	3	49	-94%
Putney Bridge to London Bridge	48	5	43	-90%
London Bridge to Greenwich	48	5	43	-90%
Greenwich to Henley Road	7	7	0	0%
Henley Road to Crossness	5	3	+ 2	-40%
Maximum Spill Frequency in the tidal Thames	**52**	**7***	**45**	**-86%**

** 7 spills from all CSOs along the tidal Thames. For the 34 targeted unsatisfactory CSOs controlled by the Thames Tideway Tunnel project, this is reduced to no more than 5 spills.*

Vol 3 Table 14.6.9 Surface water – Annual spill duration in the Typical Year climate change case

Location	2080s base case - maximum (Scenario 4) spill duration (hours)	2080s development case (Scenario 5) - maximum spill duration (hours)	Change from 2080s base case	% change from 2080s base case
Teddington to Putney Bridge	727	18	-709	-98%
Putney Bridge to London Bridge	98	53	-45	-46%
London Bridge to Greenwich	396	46	-350	-88%
Greenwich to Henley Road	10	10	0	0%
Henley Road to Crossness	30	28	-2	- 7%
Maximum Spill Duration	**727**	**53**	**-674**	**-93%**

14.6.27 The catchment modelling results for the 2080 climate change scenario (Scenario 5) show that for the Typical Year there would be:

a. a reduction of 83% in the total volume of combined sewage entering the river, from 20,800,000 m^3 to 3,480,000m^3 ie, -17,320,000m^3 fewer than the 2080 base case (Scenario 4)

b. a reduction of 93% in the maximum number of CSO spill events, from 52 to 7 across the tidal Thames, 45 events fewer than the 2080 base case (Scenario 4). For the 34 CSOs targeted by the Thames Tideway Tunnel project, this is reduced to no more than 5 CSO spills in the Typical Year.

c. a reduction of 93% in the maximum length of time that spills would occur from all of the CSOs to the tidal Thames, from 727 hours in a year to 53 hours, 674 hours fewer than the 2080 base case (Scenario 5).

14.6.28 The effects of climate change on *TTSS* DO standard compliance established are shown below in Vol 3 Table 14.6.10.

Vol 3 Table 14.6.10 Surface water – 2080s *TTSS* DO standard compliance

DO standard	1	2	3	4
DO value and tidal duration threshold	**4 mg/l for 29 tides[x]**	**3 mg/l for 3 tides**	**2 mg/l for 1 tide**	**1.5 mg/l for 1 tide**
Allowable exceedances in 41 years (frequency)	**41 (1:1yr)**	**13 (1:3yr)**	**8 (1:5yr)**	**4 (1:10yr)**
2080 base case (scenario 4)	162	75	25	13
	Fails	Fails	Fails	Fails
2080 development case (Scenario 5)	99	14	4	2
	Fails[xi]	Fails	Passes	Passes

14.6.29 Vol 3 Table 14.6.10 demonstrates that the Thames Tideway Tunnel project substantially reduces the number of exceedances compared to the 2080 base case. Without the Thames Tideway Tunnel project, the tidal Thames would continue to fail all four DO standards and would move back towards the current baseline DO compliance conditions (see para. 14.4.25).

14.6.30 There are many factors that affect the DO compliance in the river, in particular water quality is sensitive to temperature. The increase in temperature of around 2.5 ^{o}C in the 2080s (see para. 14.6.23) is equivalent to an associated reduction of about 0.5mg/l of DO carrying capacity in the river. Therefore a reduction of oxygen solubility of 0.5mg/l could result in a rise in the number of events that exceeds this threshold. Vol 3 Table 14.6.7 to Vol 3 Table 14.6.10 demonstrate that the water quality improvements to the tidal Thames would still occur in the 2080 development case compared to the 2080 base case.

14.6.31 The Thames Tideway Tunnel would however continue to intercept the same volumes of CSO discharges, irrespective of climate change and so no adaptation measures are required in respect of tunnel performance

14.7 Cumulative effects assessment

14.7.1 Considerable improvements in the water quality of the tidal Thames will occur as a result of the works associated with the proposed sewage works

[x] A tide is a single ebb or flood

[xi] Failure occurs when the predicted number of exceedances is greater than the allowable number of exceedances over the number of years of CTP events simulated

upgrades and the Lee Tunnel. These already form part of the base case and so are not considered as part of the assessment of cumulative effects.

14.7.2 Of the phases of the developments described in Vol 3 Appendix A.1, which could potentially give rise to cumulative project wide construction effects, it is not considered that they would lead to cumulative effects on surface water. This is because although some of the developments would be adjacent to tidal Thames or use river transport the uses are not of sufficient scale such that they are likely to generate significant project wide effects in relation to surface water quality.

14.7.3 No projects have been identified in Vol 3 Appendix A.1 that would be under construction during Year 1 of operation, therefore a cumulative effects assessment has not been undertaken for the operational phase. The effects on surface water would therefore remain as described in Section 14.5 and Section 14.6 above.

14.8 Mitigation

14.8.1 No significant project-wide adverse effects on surface water have been identified for either the construction or operation phases and therefore no mitigation is proposed.

14.9 Residual effects assessment

Construction effects

14.9.1 No adverse effects have been identified for the construction of the proposed development.

Operational effects

14.9.2 The residual operational effects are **major beneficial** for the improvements to water quality (spill frequency and DO) and **moderate beneficial** for the improvements to exposure to pathogens and sewage litter discharge.

14.10 Project-wide effects assessment summary

Vol 3 Table 14.10.1 Surface water – summary of construction assessment

Receptor	Effect	Significance of effect	Mitigation	Significance of residual effect
Thames Upper and Middle	The assessment has not identified any likely significant effects.	N/A	N/A	N/A

Vol 3 Table 14.10.2 Surface water – summary of operational assessment

Receptor	Effect	Significance of effect	Mitigation	Significance of residual effect
Thames Upper and Middle	Compliance with UWWTD and Dissolved Oxygen standards set by *TTSS*. Moving an additional 13km of the tidal Thames to 'good potential' from 'moderate potential and help with compliance to the WFD DO standards. Improved water quality by reducing pollutant loading through the reduction of CSO spill frequency, duration and volume along the tidal Thames.	Major beneficial	None	Major beneficial
Thames Upper and Middle	Risk of exposure days to pathogens would be reduced	Moderate beneficial	None	Moderate beneficial
Thames Upper and Middle	Sewage derived litter discharge would be reduced, improving the aesthetic quality of the river	Moderate beneficial	None	Moderate beneficial
Thames Upper and Thames Middle	Change in channel morphology caused by permanent foreshore/in-channel structures and foreshore sites	Minor adverse	See Section 5	Minor adverse

14.11 Summary of significant effects at all sites

14.11.1 Significant beneficial effects on surface water resources have been identified at a number of sites as a result of CSO interceptions. The operation of the Thames Tideway Tunnel project would improve water quality by reducing pollutant loading through the reduction of CSO spill frequency, duration and volume along the tidal Thames. Vol 3 Table 14.11.1 provides a summary of the significant effects identified at individual sites across the project.

14.11.2 No significant adverse effects either during construction or operation are anticipated as a result of the Thames Tideway Tunnel project, thus no mitigation measures have been proposed and the significance of residual effects would remain unchanged.

Vol 3 Table 14.11.1 Surface water – summary of significant effects at all sites

Significance of effect	Receptor	Description of effect	Sites with significant effects (pre-mitigation)	Sites with significant residual effects
Operation - beneficial	Thames Upper and Middle, including: • Beverley Brook (Motspur Park to Thames) • Pyl Brook at West Barnes	Compliance with UWWTD and WFD. Improved water quality in the vicinity of the intercepted CSO by reduced pollutant loading and not reducing dissolved oxygen levels due to reduced spill frequency, duration and volume	Acton Storm Tanks (Vol 4 Section 14) Albert Embankment Foreshore (Vol 16 Section 14) Barn Elms (Vol 6 Section 14), Blackfriars Bridge Foreshore (Vol 18 Section 14) Chelsea Embankment Foreshore (Vol 13 Section 14) Cremorne Wharf Depot (Vol 12 Section 14) Falconbrook Pumping Station (Vol 11 Section 14) Hammersmith Pumping Station (Vol 5 Section 14) Heathwall Pumping Station (Vol 15 Section 14) Putney Embankment Foreshore (Vol 7 Section 14) Victoria Embankment Foreshore (Vol 17 Section 14)	Acton Storm Tanks (Vol 4 Section 14) Albert Embankment Foreshore (Vol 16 Section 14) Barn Elms (Vol 6 Section 14), Blackfriars Bridge Foreshore (Vol 18 Section 14) Chelsea Embankment Foreshore (Vol 13 Section 14) Cremorne Wharf Depot (Vol 12 Section 14) Falconbrook Pumping Station (Vol 11 Section 14) Hammersmith Pumping Station (Vol 5 Section 14) Heathwall Pumping Station (Vol 15 Section 14) Putney Embankment Foreshore (Vol 7 Section 14) Victoria Embankment Foreshore (Vol 17 Section 14)
	Thames Upper and Middle, including: • Beverley Brook (Motspur Park	Risk of exposure days to pathogens would be reduced in the Typical Year	Acton Storm Tanks (Vol 4 Section 14) Albert Embankment Foreshore (Vol 16 Section 14) Barn Elms (Vol 6 Section 14)	Acton Storm Tanks (Vol 4 Section 14) Albert Embankment Foreshore (Vol 16 Section 14) Barn Elms (Vol 6 Section 14)

Significance of effect	Receptor	Description of effect	Sites with significant effects (pre-mitigation)	Sites with significant residual effects
	to Thames) • Pyl Brook at West Barnes		Blackfriars Bridge Foreshore (Vol 18 Section 14) Chelsea Embankment Foreshore (Vol 13 Section 14) Cremorne Wharf Depot (Vol 12 Section 14) Falconbrook Pumping Station (Vol 11 Section 14) Hammersmith Pumping Station (Vol 5 Section 14) Heathwall Pumping Station (Vol 15 Section 14) Putney Embankment Foreshore (Vol 7 Section 14) Victoria Embankment Foreshore (Vol 17 Section 14)	Blackfriars Bridge Foreshore (Vol 18 Section 14) Chelsea Embankment Foreshore (Vol 13 Section 14) Cremorne Wharf Depot (Vol 12 Section 14) Falconbrook Pumping Station (Vol 11 Section 14) Hammersmith Pumping Station (Vol 5 Section 14) Heathwall Pumping Station (Vol 15 Section 14) Putney Embankment Foreshore (Vol 7 Section 14) Victoria Embankment Foreshore (Vol 17 Section 14)
	Thames Upper and Middle, including: • Beverley Brook (Motspur Park to Thames) • Pyl Brook at West Barnes	Sewage derived litter discharge from the intercepted CSO would be reduced improving the aesthetic quality of the river locally.	Acton Storm Tanks (Vol 4 Section 14) Albert Embankment Foreshore (Vol 16 Section 14) Barn Elms (Vol 6 Section 14), Blackfriars Bridge Foreshore (Vol 18 Section 14) Chelsea Embankment Foreshore (Vol 13 Section 14) Cremorne Wharf Depot (Vol 12 Section 14)	Acton Storm Tanks (Vol 4 Section 14) Albert Embankment Foreshore (Vol 16 Section 14) Barn Elms (Vol 6 Section 14), Blackfriars Bridge Foreshore (Vol 18 Section 14) Chelsea Embankment Foreshore (Vol 13 Section 14) Cremorne Wharf Depot (Vol 12 Section 14)

Significance of effect	Receptor	Description of effect	Sites with significant effects (pre-mitigation)	Sites with significant residual effects
			Falconbrook Pumping Station (Vol 11 Section 14) Hammersmith Pumping Station (Vol 5 Section 14) Heathwall Pumping Station (Vol 15 Section 14) Putney Embankment Foreshore (Vol 7 Section 14) Victoria Embankment Foreshore (Vol 17 Section 14)	Falconbrook Pumping Station (Vol 11 Section 14) Hammersmith Pumping Station (Vol 5 Section 14) Heathwall Pumping Station (Vol 15 Section 14) Putney Embankment Foreshore (Vol 7 Section 14) Victoria Embankment Foreshore (Vol 17 Section 14)
	Thames Middle: • including Deptford Creek • Regents Canal [Lower Section]) • St Saviour's Dock	Compliance with UWWTD and WFD. Improved water quality in the vicinity of the intercepted CSO by reduced pollutant loading and not reducing dissolved oxygen levels due to reduced spill frequency, duration and volume	Deptford Church Street (Vol 23 Section 14) Greenwich Pumping Station (Vol 24 Section 14) Earl Pumping Station (Vol 22 Section 14) King Edward Memorial Park Foreshore (Vol 21 Section 14) Minor works sites (Vol 27 Section 14) Shad Thames Pumping Station (Vol 19 Section 14)	Deptford Church Street (Vol 23 Section 14) Greenwich Pumping Station (Vol 24 Section 14) Earl Pumping Station (Vol 22 Section 14) King Edward Memorial Park Foreshore (Vol 21 Section 14) Minor works sites (Vol 27 Section 14) Shad Thames Pumping Station (Vol 19 Section 14)
	Thames Middle: • including Deptford Creek • Regents Canal	Risk of exposure days to pathogens would be reduced in the Typical Year	Deptford Church Street (Vol 23 Section 14) Greenwich Pumping Station (Vol 24 Section 14) Earl Pumping Station (Vol 22	Deptford Church Street (Vol 23 Section 14) Greenwich Pumping Station (Vol 24 Section 14) Earl Pumping Station (Vol 22

Significance of effect	Receptor	Description of effect	Sites with significant effects (pre-mitigation)	Sites with significant residual effects
	[Lower Section]) • St Saviour's Dock		Section 14) King Edward Memorial Park Foreshore (Vol 21 Section 14) Minor works sites (Vol 27 Section 14) Shad Thames Pumping Station (Vol 19 Section 14)	Section 14) King Edward Memorial Park Foreshore (Vol 21 Section 14) Minor works sites (Vol 27 Section 14) Shad Thames Pumping Station (Vol 19 Section 14)
	Thames Middle: • including Deptford Creek • Regents Canal [Lower Section]) • St Saviour's Dock	Sewage derived litter discharge from the intercepted CSO would be reduced improving the aesthetic quality of the river locally.	Deptford Church Street (Vol 23 Section 14) Greenwich Pumping Station (Vol 24 Section 14) Earl Pumping Station (Vol 22 Section 14) King Edward Memorial Park Foreshore (Vol 21 Section 14) Minor works sites (Vol 27 Section 14) Shad Thames Pumping Station (Vol 19 Section 14)	Deptford Church Street (Vol 23 Section 14) Greenwich Pumping Station (Vol 24 Section 14) Earl Pumping Station (Vol 22 Section 14) King Edward Memorial Park Foreshore (Vol 21 Section 14) Minor works sites (Vol 27 Section 14) Shad Thames Pumping Station (Vol 19 Section 14)
	Thames Middle Wandle (Croydon to Wandsworth) and the R. Graveney	Compliance with UWWTD and WFD. Improved water quality in the vicinity of the intercepted CSO by reduced pollutant loading and not reducing dissolved oxygen levels due to reduced spill frequency, duration and	Dormay Street (Vol 8 Section 14) King George's Park (Vol 9 Section 14)	Dormay Street (Vol 8 Section 14) King George's Park (Vol 9 Section 14)

Significance of effect	Receptor	Description of effect	Sites with significant effects (pre-mitigation)	Sites with significant residual effects
		volume		
	Thames Middle Wandle (Croydon to Wandsworth) and the R. Graveney	Risk of exposure days to pathogens would be reduced in the Typical Year	Dormay Street (Vol 8 Section 14) King George's Park (Vol 9 Section 14)	Dormay Street (Vol 8 Section 14) King George's Park (Vol 9 Section 14)
	Thames Middle Wandle (Croydon to Wandsworth) and the R. Graveney	Sewage derived litter discharge from the intercepted CSO would be reduced improving the aesthetic quality of the river locally.	Dormay Street (Vol 8 Section 14) King George's Park (Vol 9 Section 14)	Dormay Street (Vol 8 Section 14) King George's Park (Vol 9 Section 14)

References

[1] The Council Directive 91/271/EEC concerning urban waste-water treatment.

[2] The Urban Waste Water Treatment (England and Wales) Regulations 1994.

[3] The Water Environment (Water Framework Directive) (England and Wales) Regulations 2003.

[4] Environment Agency. *Thames River Basin Management Plan* (2009).

[5] The United Kingdom Technical Advisory Group (UKTAG) to the WFD. Available at: *http://www.wfduk.org/*

[6] Environment Agency. *River Basin Management Plan, Thames River Basin District* (2009)

[7] *The Thames Recreational Users Study Final Report.* A collaborative partnership project between the City of London Port Health Authority and the Health Protection Agency (2007).

[8] Thames Water. *Thames Tideway Strategic Study* (February 2005).

[9] Foundation for Water Research. *Urban Pollution Management Manual Second Edition* (1998)

[10] UK Technical Advisory Group on the Water Framework Directive. *UK Environmental Standards and Conditions (Phase 1) Final report* (2008)

[11] Office of National Statistics. 2001 *National Census.* (April 2001).

[12] British Water, *British Water Code of Practice, Flows and Loads – 3, Sizing Criteria, Treatment Capacity for Sewage Treatment Systems (2009).*

[13] HR Wallingford, (2006). See citation above

[14] Environment Agency. *Thames River Basin Management Plan* (2009).

Thames Tideway Tunnel
Thames Water Utilities Limited

Thames Water

Application for Development Consent

Application Reference Number: WWO10001

Environmental Statement

Doc Ref: **6.2.03**

Volume 3: Project-wide effects assessment

Section 15: Water resources - flood risk

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

Hard copy available in

Box **17** Folder **A**
January 2013

Thames Tideway Tunnel
Creating a cleaner, healthier River Thames

This page is intentionally blank

Thames Tideway Tunnel

Environmental Statement

Volume 3: Project-wide effects assessment

Section 15: Water resources – flood risk

List of contents

Page number

List of plates

Page number

List of tables

Page number

15 Water resources – flood risk

15.1 Introduction

15.1.1 This section represents a project-wide Flood Risk Assessment (FRA) prepared in accordance with the requirements of the National Policy Statement for Waste Water (NPS) (DEFRA, 2012)[1] covering effects of construction and operation across the project on the Thames Tideway.

15.1.2 A summary of significant effects identified at the site-specific level across the project is provided in Section 15.7.

15.2 Scope of project-wide flood risk assessment

15.2.1 Given the nature of this project, there could be project-wide effects which arise due to the accumulation of all effects across the project. The location of sites within the River Thames would have a number of impacts on the River Thames system and associated watercourses including the potential reduction of volume within the River Thames and possible subsequent increase in flood risk. The impact of this, both during construction and as a result of the operational development, has been assessed through 2D hydrodynamic and physical modelling work.

15.2.2 The scope of the flood risk project-wide assessment is to:

a. Consider the implications of the project on tidal and fluvial flood risk to surrounding areas through changes in water levels as a result of built footprint in the foreshore, flood defence changes and scour implications.

b. Identify any residual risks with respect to flood risk both to and from the project.

c. Other sources of flooding such as surface water, groundwater and artificial sources have been scoped out at the project-wide scale and are considered within the site specific FRAs.

15.2.3 A cumulative assessment has been scoped out of the project-wide flood risk assessment. This is on the assumption that the potential flood sources from other developments in the floodplain that could contribute to the cumulative effect of flood risk are predominantly surface water as groundwater implications have been considered in the project-wide groundwater section in this volume and scoped out on significance.

15.2.4 All new developments in the floodplain are considered under the National Planning Policy Framework (NPPF) (Communities and Local Government, 2012)[2] with respect to flood risk both to and from the development. A key requirement of the flood risk policy is that there is no increase in flood risk as a result of development. In addition to this, the *London Plan 2011* (GLA, 2011)[3] outlines an essential standard of a 50% attenuation requirement to surface water from all new developments. Therefore the Thames Tideway Tunnel project has agreed to meet the essential standard at each of the development sites that are not discharging to tidal watercourses, which would ensure there is no increase in surface water flood risk from the site. Neighbouring new and proposed developments would also be subject to the NPPF and the *London Plan 2011* flood risk policies and hence the same considerations of flood risk. Therefore, given the project's commitment to surface water attenuation and the likely assumption that surrounding new developments would also incorporate suitable attenuation, the surface water flood risk from the project sites would not contribute to a cumulative effect and therefore the impact is not considered significant and has been scoped out.

15.3 Elements of the proposed development relevant to flood risk

15.3.1 The proposed development is described in Section 3 of this volume, with further details of each site described in Section 3 of Vols 4 to 27. The elements of the proposed development relevant to flood risk are set out below.

Construction

15.3.2 The majority of the construction effects would be local to each of the construction sites and are assessed in each of the site specific volumes. There is however the potential for flood risk to increase within the Tidal Thames and to surrounding areas due to following construction and activities:

a. temporary development in the foreshore/floodplain creating a loss of storage

b. temporary development in the foreshore creating scour of river bed in and around flood defence structures that could affect crest levels and/or defence stability

c. tunnelling under river walls causing settlement of flood defences (along the tunnel route)

d. works to flood defences causing changes in residual risk

e. changes to sewer network outfall location and size.

Code of Construction Practice

15.3.3 Appropriate guidance regarding flood defence construction and emergency planning are included in the *Code of Construction Practice (CoCP)*[i] *Part A* (Section 8). The relevant measures are summarised in this section.

15.3.4 The *CoCP Part A* (Section 8) requires that no temporary living accommodation be permitted onsite and that an evacuation route and safe refuge should be provided in the event of a flood event.

---

[i] The *Code of Construction Practice (CoCP)* is provided in Vol 1 Appendix A. It contains general requirements (*Part A*), and site specific requirements for this site (*Part B*).

15.3.5 The *CoCP Part A* (Section 8) requires the contractor to provide and maintain continuous flood defence protection, for both permanent and temporary works, to the statutory flood defence level[ii] as detailed within the FRA. This is a requirement of the Thames River Protection of Floods Amendment Act 1879 (Great Britain, 1879)[4].

Operation

15.3.6 As for the construction phase, the majority of the operational effects would be local to each of the sites and are assessed in each of the specific volumes. There is however the potential for flood risk to increase within the Tidal Thames and to surrounding areas due to the following operational activities:

a. Permanent development in the foreshore/floodplain creating loss of storage

b. Permanent development in the foreshore creating scour of river bed in and around flood defence structures that could affect crest levels and/or defence stability

c. changes to sewer network outfall location and size (through operation of the tunnel)

d. works to flood defences causing changes in residual risk

15.4 Regulatory context

15.4.1 This project-wide FRA has been prepared in accordance with the Waste Water NPS and associated NPPF and technical guidance (Communities and Local Government, 2012)[5].

15.4.2 In accordance with the NPS and NPPF, a main aim of an FRA is to assess the risk of all forms of flooding to and from a proposed development and ensure appropriate measures are incorporated so that the development is safe from flooding and does not increase the flood risk to the surrounding area. FRAs also inform the Sequential Test and the Exception Test if appropriate. These tests are described in the following section.

Sequential Test

15.4.3 The Waste Water NPS aims to ensure that flood risk is taken into account at all stages of the planning process, directing development towards low risk areas through the use of a sequential approach which avoids inappropriate development in areas at risk of flooding. The Sequential Test requires that preference should be given to locating projects in Flood Zone 1 although if there is no "reasonably available site" in Flood Zone 1 then projects should be located in Flood Zone 2. However if there is no "reasonably available site" in Flood Zones 1 or 2, then nationally significant waste water infrastructure projects can be located in Flood Zone 3 subject to the Exception Test (see below).

[ii] The level to which the flood defences must be maintained to ensure that both the sites themselves and third-party land and assets in the surrounding area are protected from flooding.

15.4.4 An extensive site selection process has been followed to identify sites to be included within the proposals. As part of the site selection process a review was undertaken for all site options with respect to Flood Zone, standard of flood defence and sustainable drainage measure (SuDS) suitability and this information used to assess the implications of flooding to each site option. This was then used in the overall decision making process for site selection.

15.4.5 Where combined sewer overflows (CSOs) require interception or other forms of control, the location of possible construction sites and interception points has normally been limited to sites in close proximity to the CSOs and therefore most have tended to be close to (or on) the foreshore where the CSO is located. As a consequence of the CSO interception requirement, most CSO sites (and some of the viable alternatives) would lie within Flood Zones 3a and 3b. Furthermore, the main tunnel alignment along the course of the River Thames, as well as the acknowledged importance of seeking to use a high proportion of barging for export of excavated materials, requires that most main tunnel sites are also located close to the foreshore. As with the CSO sites, this means that most of the main tunnel sites (and most viable alternatives) are located within Flood Zone 3a and 3b. Further detail regarding alternative sites is included in Vol 1 Section 3.

Exception Test

15.4.6 The Waste Water NPS states that the Exception Test should be applied where it is not possible for the project to be located in zones of lower probability of flooding than Flood Zone 3.

15.4.7 The requirements of the Exception Test are provided in Section 4.4.15 of the NPS. The test requires overall sustainability benefits (part a) to outweigh flood risk, whilst ensuring the development is safe and does not increase flood risk elsewhere (part c) and is preferably located on previously developed land (part b). The project-wide Exception Test is detailed in Section 15.6 of this report.

15.5 Assessment of flood risk

15.5.1 The following section considers the relevant activities in relation to their project-wide influence both to the development and as a result of the development.

15.5.2 This assessment is based on a FRA screening exercise that identified relevant potential flood sources and pathways but has used the most recent information available. The tidal and fluvial assessments were based on the Flood Zones which do not take account of the presence of existing defences.

15.5.3 This section builds on the FRA screening exercise using the most recent information for the project, as outlined in the methodology set out within Vol 2 Environmental assessment methodology.

15.5.4 The methodology used for the assessment of effects on flood risk and its significance is described in full in Vol 2. The methodology differs slightly from a typical environmental impact assessment (EIA) methodology. For other topics, the likely significance of an effect is determined by assessing the magnitude of an impact against the vulnerability or sensitivity of a receptor. However, due to the nature of flood risk assessments, the risk based approach outlined in the NPS and NPPF is considered preferable. This approach is based on the probability of an event occurring as a result of the proposed development rather than a direct change in conditions in combination with the consequences if the event were to occur

15.5.5 The aim of an FRA is to assess the risk of all forms of flooding to and from a development. The FRAs undertaken for the Thames Tideway Tunnel project assess the effects of construction and operation for the lifetime of the project (taking into consideration climate change) on the relevant watercourses, for both project-wide effects and at the site-specific scale. The risk-based approach can be applied through the application of the source-pathway-receptor model and this approach is used for the FRAs within this *Environmental Statement.*

Tidal and fluvial flood risk

15.5.6 The local tidal and fluvial flood risk to each site has been assessed in each of the site specific volumes. At the project-wide scale the implications on tidal and fluvial flood risk have been assessed through the outcomes of a series of supporting studies that are summarised in this section.

Tidal flow modelling

15.5.7 A hydraulic modelling study has been completed as part of the Thames Tideway Tunnel project to assess the impacts of the proposed foreshore works in the River Thames in terms of water level and tidal phasing (HR Wallingford, 2012)[6] and this is included as Vol 3 Appendix M.1. The Thames Tideway Tunnel project proposals include eight foreshore sites where temporary works (including solid structures) would be present during the construction phase. At seven of these sites, smaller permanent operational structures would remain within the tideway.

15.5.8 The proposed works are within the tidal reaches of the River Thames, and have been assessed through hydraulic modelling to determine the changes associated with the footprints of the proposed structures for both the permanent and temporary works.

15.5.9 The hydraulic modelling was used to assess a range of scenarios, examining the various impacts of the works depending upon the state of the tide, fluvial influence and closure of the Thames Barrier. The most relevant results from the study are as follows:

a. In all scenarios modelled, the permanent works had less of an impact on levels than the temporary works (the temporary works provide the worst case scenario).

b. The structures in the foreshore act as a barrier to tidal flow, reducing the flow of the flood tide up the river so the tidal phase is slowed marginally as a result of both the permanent and temporary works.

c. As a result of this slight reduction in propagation of the tide upstream, there is an increased volume of flood storage available in the tideway for most scenarios. This increased volume is greater than the volume lost to the works themselves as a result of both temporary and permanent works, resulting in a net gain of flood storage.

d. Fluvially dominated scenarios show existing (ie no scheme) out of bank flooding in the upper reaches at Richmond with a small increase in water levels. The significance of this is examined further in15.5.14.

15.5.10 The scenarios undertaken for the study that were agreed with the Environment Agency (EA) are outlined below and the reasons for their selection included in more detail in the modelling report:

a. High Water at Southend 3.85 OD (N) and mean daily flow at Teddington (65 m^3/s)

b. High Water at Southend 3.85 OD (N) and 0 flow at Teddington

c. High Water at Southend 2.75 OD (N) and 1:100 year flow (800 m^3/s)

d. High Water at Southend 2.75 OD (N) and 0 flow at Teddington

e. Mean tide (HW at Southend 2.4 OD (N) and daily flow at Teddington 65 m^3/s)

f. Mean spring tide (HW at Southend 2.9 OD (N) and largest flow for Barrier open for this tide (736 m^3/s)

g. Most extreme fluvial flow for Barrier open (1051 m^3/s and HW at Southend 2.35 OD (N)

h. Barrier closure case – 13-14th December 2000. HW Southend up to 3.4 OD (N) and flow up to 450 m^3/s.

15.5.11 Scenario test a) is considered to represent the worst case scenario for tidally dominated reaches with respect to water level conditions as it generates the highest water level possible with the barrier remaining open. The results of scenario a) for the temporary (worst case) scenario are summarised from Table 6 of the report as:

a. the maximum predicted increase in tide level at any phase of the tide is 46mm at Chelsea

b. the maximum predicted decrease in tide level at any phase of the tide is 74mm at Richmond

c. the maximum predicted increase in peak tide level is 5mm between Charlton-Tilbury

d. the maximum predicted decrease in peak tide level is 38mm between Teddington-Richmond.

15.5.12 The permanent works results for scenario a) have less of an impact than the temporary works and are summarised below:

a. the maximum predicted increase in tide level at any phase of the tide is 15mm at Chelsea

b. the maximum predicted decrease in tide level at any phase of the tide is 62mm at Richmond

c. the maximum predicted increase in peak tide level is 2mm between Charlton-Tilbury

d. the maximum predicted decrease in peak tide level is 21mm between Teddington-Richmond.

15.5.13 Other test scenarios included within the assessment examine the effects of different parameters on water levels and include barrier closure events, fluvial extreme events and extreme barrier open events. The results (for the worst case scenarios) are summarised as:

a. the maximum predicted increase in tide level at any phase of the tide is 86mm at Chelsea

b. the maximum predicted decrease in tide level at any phase of the tide is 95mm at Richmond

c. the maximum predicted increase in peak tide level is 17mm between Richmond-Chelsea

d. the maximum predicted decrease in peak tide level is 44mm between Teddington-Richmond

e. the predicted effects of the works on the tide levels are insufficient to require any changes to the present operation of the Thames Barrier as identified in the modelling report and through consultation with the EA on the modelling results.

15.5.14 The results show that, although the net effect is a gain in flood storage within the Tideway for tidally dominated scenarios, this effect is spatially variable (depending on tidal and fluvial conditions) and some flow scenarios would result in marginally increased high tide levels in some locations and marginal decreased high tide levels in others.

15.5.15 For this reason a comparison has been made in this FRA of the maximum predicted changes in peak water level against the existing flood defence levels in the tidal reaches (Vol 3 Table 15.5.2). This compares changes in freeboard during the 1 in 200 year climate change event as a result of the proposed development.

Fluvial implications

15.5.16 The hydraulic modelling study referred to in para.15.5.7 also includes fluvial scenarios to assess the effects of the proposed works on fluvially dominated scenarios. These include scenario c) as outlined in para. 15.5.10 which represents the 1 in 100 year fluvial flow and scenario g) which includes the largest fluvial flow without barrier closure (scenario g is an extreme case with a return period of greater than the 1 in 500 year fluvial flow).

15.5.17 Scenario test g) is considered to show the worst case scenario for fluvially dominated reaches with respect to water level conditions. The results of scenario g) for the temporary (worst case) scenario are summarised from Table 30 of the report as:

a. the maximum predicted increase in tide level at any phase of the tide is 86mm at Chelsea.

b. the maximum predicted decrease in tide level at any phase of the tide is 12mm at Tower Bridge.

c. the maximum predicted increase in peak tide level is 17mm between Richmond- Chelsea

d. the maximum predicted decrease in peak tide level is 2mm between Westminster- Charlton.

15.5.18 The hydraulic modelling report identifies that during test scenarios c), f) and g) out of bank flows are experienced in the existing baseline model in the Teddington to Richmond reach of the River Thames. The maximum increases in water level in relation to existing defence heights are outlined in Vol 3 Table 15.5.1. It should be noted that the modelling methodology does not represent out of bank flows for the fluvial scenarios (ie the model has ‘glass walls’) so the maximum water levels predicted for existing, temporary and permanent scenarios are considered a conservative approach for the upper reaches of the River Thames. The predicted water levels for the upper reaches are therefore higher than would be expected and represent a worst-case scenario.

15.5.19 Vol 3 Plate 15.5.1-Vol 3 Plate 15.5.3 present the same information contained in the hydraulic modelling study in Vol 3 Appendix M.1 but at a greater resolution for the upstream reach for the fluvially dominated scenarios to display the changes between the existing, temporary and permanent works on water level. The most significant out of bank flows (ie overtopping of flood defences) occurs during scenario g). It is important to note that the water levels for the existing, temporary and permanent cases are not significantly different and therefore are difficult to differentiate on the graphs.

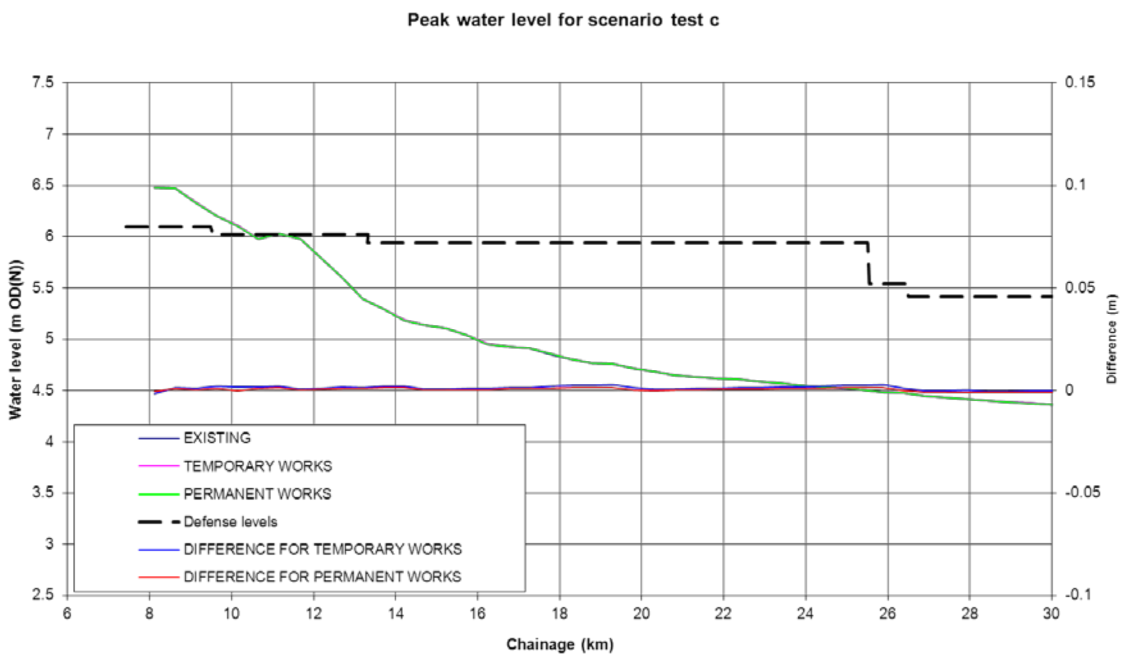
15.5.20 A comparison of peak water level against flood defence heights for the maximum increase in the Teddington- Richmond reach has been included in Vol 3 Table 15.5.1. This shows that for all scenarios the maximum increases as a result of the temporary or permanent case do not change the overtopping status of the flood defences, ie defences that do not flood in the existing scenario are not predicted to overtop as a result of the proposed works.

15.5.21 Vol 3 Table 15.5.1shows that the maximum increase in peak water level during the fluvially dominated scenarios is higher for the temporary case for tests c), f) and g). The maximum increase in the Teddington- Richmond reach for scenario c) and f) for both temporary and permanent scenarios is experienced at the Ham House/ Marble Hill Park location. This location consists of low vulnerability open space and parkland on both river banks and the consequence of a maximum peak water level increase of 2mm during the temporary scenario and a maximum peak water level increase of 1mm during the permanent scenarios would not be considered to have a significant impact on the flood defence standard or flood risk at this location, which is already exceeded by floodwater in the existing scenario.

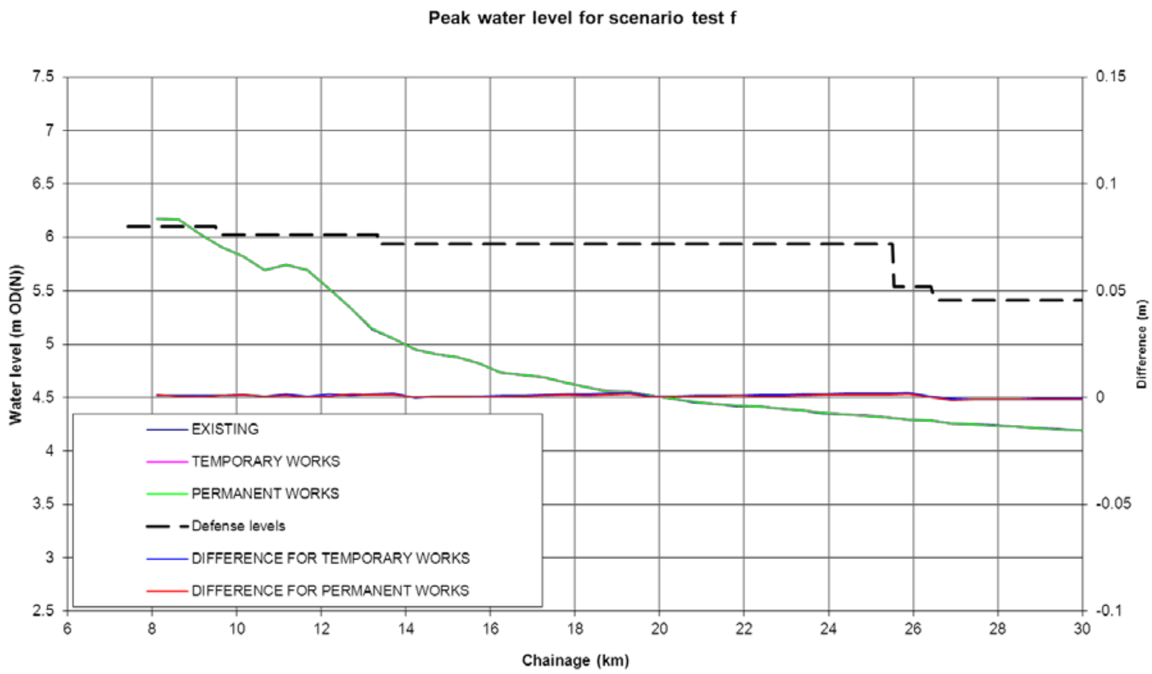
15.5.22 For scenario g) the maximum peak water level increase for the temporary scenario also occurs at the Ham House/ Marble Hill Park location. As noted above, this area consists of low vulnerability open space and parkland on both river banks and the consequence of a 6mm increase during the temporary scenario would not be considered to have a significant impact on the flood defence standard or flood risk at this location, which is already exceeded by floodwater in the existing scenario.

15.5.23 For scenario g) the maximum peak water level increase experienced in the Teddington-Richmond reach for the permanent scenario is located further downstream at Corporation Island with a predicted increase of 4mm on the flood water levels for the left bank, associated with a correlating decrease of 4mm in the available freeboard for the right bank. This location is predominantly open space with no vulnerable receptors and this increase does not result in a change in the standard of flood defence protection or flood risk during this scenario for the left bank, which is already exceeded by floodwater. Therefore in overall consideration of the vulnerability of adjacent land uses at this location (which are largely open space, parking and gardens along the riverside) and the conservative nature of the predicted water levels, these minor increases are not considered to be significant.

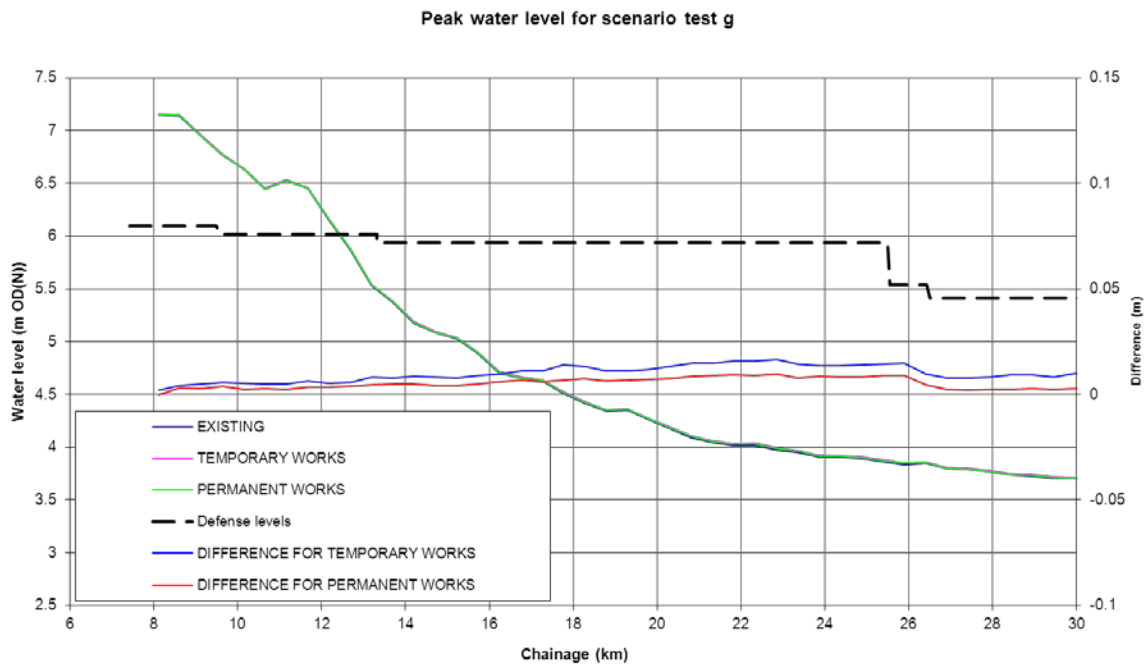
Vol 3 Plate 15.5.1 Flood risk – graph to show high resolution of Test c) maximum water level results at upstream extent of the hydraulic model



Vol 3 Plate 15.5.2 Flood risk – graph to show high resolution of Test f) maximum water level results at upstream extent of the hydraulic model.



Vol 3 Plate 15.5.3 Flood risk – graph to show high resolution of Test g) maximum water level results at upstream extent of the hydraulic model.



Freeboard consideration

15.5.24 The implications on flood defence freeboard, of increases and decreases in the tidal Thames water levels caused by the proposed temporary and permanent works, are outlined in Vol 3 Table 15.5.2.

15.5.25 It should be noted that the EA periodically update their modelled peak water levels for the 1 in 200 year return period event (including climate change). Therefore the *CoCP Part A* (Section 8) states that the contractor will be responsible for obtaining from the EA updated modelled water levels (for the 1 in 200 year return period event including climate change) relevant at the time of construction as well as updated information on the required standard of protection of the flood defences.

Vol 3 Table 15.5.1 Flood risk – fluvially dominated case water level information and freeboard analysis for the Teddington- Richmond reach

Hydraulic Modelling scenario	Maximum increase in water levels (metres)		Location of maximum increase in river reach	Flood defence crest height (mAOD)		Existing freeboard available (minus values = overtopping) (metres)		Freeboard/ overtopping as a result of project works			
								Maximum increase for Temporary case		Maximum increase for Permanent case	
	Temporary	Permanent		Left Bank	Right Bank	Left Bank	Right Bank	Left Bank	Right Bank	Left Bank	Right Bank
Scenario c)	0.002	0.001	Ham House/ Marble Hill Park (chainage 11.162)	5.54	6.02	-0.486	-0.006	-0.488	-0.008	-0.487	-0.007
Scenario f)	0.002	0.001	Ham House/ Marble Hill Park (chainage 11.162)	5.54	6.02	-0.199	+0.281	-0.201	+0.279	-0.20	+0.28
Scenario g)	0.006	0.004	Temporary - Ham House/ Marble Hill Park (chainage 11.162)	5.54	6.02	-0.911	-0.431	-0.917	-0.437	-0.915	-0.435

Hydraulic Modelling scenario	Maximum increase in water levels (metres)		Location of maximum increase in river reach	Flood defence crest height (mAOD)		Existing freeboard available (minus values = overtopping) (metres)		Freeboard/ overtopping as a result of project works			
								Maximum increase for Temporary case		Maximum increase for Permanent case	
	Temporary	Permanent		Left Bank	Right Bank	Left Bank	Right Bank	Left Bank	Right Bank	Left Bank	Right Bank
			Permanent - Corporation Island (chainage 12.686)	5.54	6.02	-0.333	+0.147	-0.339	+0.141	-0.337	+0.143

Vol 3 Table 15.5.2 Flood risk – summary of results and freeboard analysis for the Thames Tideway Tunnel project sites

Site	Statutory Flood Defence Level (mAOD)	National Flood and Coastal Defence Database** (NFCDD) Flood Defence Level (mAOD)	1 in 200 year water level (year 2107 – metres)	Available freeboard now (m)	Available freeboard after max. decrease in water levels – temporary (m)*	Available freeboard after max. decrease in water levels – permanent (m)*	Available freeboard after max. increase in water levels – temporary (m)*	Available freeboard after max. increase in water levels - permanent (m)*
Acton Storm Tanks	Not applicable due to distance from tidal River Thames.							
Hammersmith Pumping Station	5.54	5.79-5.80	5.08	0.71-0.72	*-0.038* 0.748-0.758	*-0.018* 0.728-0.738	*+0.017* 0.693-0.703	*+0.010* 0.70-0.71
Barn Elms	5.54	5.54-6.05	5.06	0.48-0.99	*-0.038* 0.518-1.028	*-0.018* 0.498-1.008	*+0.017* 0.463-0.973	*+0.010* 0.47-0.98
Putney Embankment Foreshore	5.54	5.54-7.16	5.06	0.48-2.1	*-0.038* 0.518-2.138	*-0.018* 0.498-2.118	*+0.017* 0.463-2.083	*+0.010* 0.47-2.09

Site	Statutory Flood Defence Level (mAOD)	National Flood and Coastal Defence Database** (NFCDD) Flood Defence Level (mAOD)	1 in 200 year water level (year 2107 – metres)	Available freeboard now (m)	Available freeboard after max. decrease in water levels – temporary (m)*	Available freeboard after max. decrease in water levels – permanent (m)*	Available freeboard after max. increase in water levels – temporary (m)*	Available freeboard after max. increase in water levels - permanent (m)*
Dormay Street	5.41	5.49-5.9	5.07	0.42-0.83	*-0.038* 0.458-0.868	*-0.018* 0.438-0.848	*+0.017* 0.403-0.813	*+0.010* 0.41-0.82
King George's Park	Not applicable due to distance from tidal River Thames.							
Carnwarth Road Riverside	5.41	5.41-7.43	5.07	0.34-2.36	*-0.038* 0.378-2.398	*-0.018* 0.358-2.378	*+0.017* 0.323-2.343	*+0.010* 0.35-2.37
Falconbrook Pumping Station	5.41	5.37-5.41	5.04	0.33-0.37	*-0.038* 0.368-0.408	*-0.018* 0.348-0.388	*+0.017* 0.313-0.353	*+0.010* 0.32-0.36
Cremorne Wharf	5.41	5.41-6.06	5.02	0.39-1.04	*-0.038* 0.428-1.078	*-0.018* 0.408-1.058	*+0.017* 0.373-1.023	*+0.010* 0.38-1.03

Site	Statutory Flood Defence Level (mAOD)	National Flood and Coastal Defence Database** (NFCDD) Flood Defence Level (mAOD)	1 in 200 year water level (year 2107 – metres)	Available freeboard now (m)	Available freeboard after max. decrease in water levels – temporary (m)*	Available freeboard after max. decrease in water levels – permanent (m)*	Available freeboard after max. increase in water levels – temporary (m)*	Available freeboard after max. increase in water levels - permanent (m)*
Chelsea Embankment Foreshore	5.41	5.41	5.0	0.41	*-0.029* 0.439	*-0.014* 0.424	*+0.013* 0.397	*+0.004* 0.406
Kirtling Street	5.41	5.69-5.88	4.99	0.7-0.89	*-0.029* 0.729-0.919	*-0.014* 0.714-0.904	*+0.013* 0.687-0.877	*+0.004* 0.696-0.886
Heathwall Pumping Station	5.41	5.82-7.33	4.99	0.83-2.34	*-0.029* 0.859-2.369	*-0.014* 0.844-2.354	*+0.013* 0.817-2.327	*+0.004* 0.826-2.336
Albert Embankment Foreshore	5.41	5.32-5.84	4.98	0.34-0.86	*-0.007* 0.347-0.867	*-0.002* 0.342-0.862	*+0.012* 0.328-0.848	*+0.004* 0.336-0.856
Victoria Embankment Foreshore	5.41	5.49	4.96	0.53	*-0.007* 0.537	*-0.002* 0.532	*+0.012* 0.518	*+0.004* 0.526

Site	Statutory Flood Defence Level (mAOD)	National Flood and Coastal Defence Database** (NFCDD) Flood Defence Level (mAOD)	1 in 200 year water level (year 2107 – metres)	Available freeboard now (m)	Available freeboard after max. decrease in water levels – temporary (m)*	Available freeboard after max. decrease in water levels – permanent (m)*	Available freeboard after max. increase in water levels – temporary (m)*	Available freeboard after max. increase in water levels - permanent (m)*
Blackfriars Bridge Foreshore	5.41	5.41-5.74	4.94	0.47-0.8	*-0.007* 0.477-0.807	*-0.002* 0.472-0.802	*+0.012* 0.458-0.788	*+0.004* 0.466-0.796
Shad Thames Pumping Station	5.28	5.3-5.92	4.92	0.38-1.0	*-0.002* 0.382-1.002	*-0.001* 0.381-1.001	*+0.014* 0.366-0.986	*+0.005* 0.375-0.995
Chambers Wharf	5.28	5.64-5.76	4.90	0.74-0.86	*-0.002* 0.742-0.862	*-0.001* 0.741-0.861	*+0.014* 0.726-0.846	*+0.005* 0.735-0.855
King Edward Memorial Park Foreshore	5.23	5.44-5.69	4.85	0.59-0.84	-0.002 0.592-0.842	*-0.001* 0.591-0.842	*+0.014* 0.576-0.826	*+0.005* 0.585-0.835
Bekesbourne Street	Not applicable as located outside tidal floodplain.							
Earl Pumping Station	Not applicable due to distance from tidal River Thames.							

Site	**Statutory Flood Defence Level (mAOD)**	**National Flood and Coastal Defence Database** (NFCDD) Flood Defence Level (mAOD)**	**1 in 200 year water level (year 2107 – metres)**	**Available freeboard now (m)**	**Available freeboard after max. decrease in water levels – temporary (m)***	**Available freeboard after max. decrease in water levels – permanent (m)***	**Available freeboard after max. increase in water levels – temporary (m)***	**Available freeboard after max. increase in water levels - permanent (m)***
Deptford Church Street	5.23	5.65-6.16	4.83	0.82-1.33	*-0.002* 0.822-1.332	*-0.001* 0.821-1.331	*+0.014* 0.806-1.316	*+0.005* 0.815-1.325
Greenwich Pumping Station	5.23	5.70-5.23	4.83	0.87-0.4	*-0.002* 0.872-0.402	*-0.001* 0.871-0.401	*+0.014* 0.856-0.386	*+0.005* 0.865-0.395
Abbey Mills Pumping Station	5.49	4.99***-5.73	4.75	0.24-0.98	*-0.002* 0.242-0.982	*-0.001* 0.241-0.981	*+0.014* 0.226-0.966	*+0.005* 0.235-0.975
Beckton Sewage Treatment Works	7.2 Thames 5.5-5.6 Barking	7.2 Thames 5.5-5.6 Barking	6.98 Thames 4.03 Barking	0.22 Thames 1.47-1.57 Barking	No decrease for this reach	No decrease for this reach	*+0.014* 0.206 Thames 1.456-1.556 Barking	*+0.004* 0.216 Thames 1.466-1.566 Barking

** Maximum decrease and increase have been identified for the specific reach relevant to the site, maximum identified levels from all tests used written in italics which equates to the loss in freeboard (positive numbers), or gain in freeboard (negative numbers).*

*** The National Flood and Coastal Defence Database is a register of all coastal and fluvial flood risk management assets. This register is due to be updated in the immediate future by the Environment Agency.*

**** The FRA for the Abbey Mills Site demonstrated the defences to be below the NFCDD level in some locations – see Vol 25 Section 15.*

Flood risk implications

15.5.26 The tidal and fluvial modelling study summarized above demonstrates that the peak water level changes are minor as a result of the proposed temporary and permanent works. Therefore it is concluded that the Thames Tideway Tunnel project would not produce a significant detrimental impact on the flood storage or peak tide levels within the tidal Thames.

15.5.27 The key findings of the modelling study are:

a. during events that do not trigger barrier closure, the permanent and temporary structures in the foreshore act as a barrier to incoming tidal flow, reducing the flow (and volume) of the flood tide progressively up the Tideway so that the tidal phase is slowed marginally as a result of the works.

b. As a consequence, there is an increased volume of flood storage available progressively up the Tideway during tidally dominated scenarios. This increased volume is greater than the volume taken up physically by the works themselves, resulting in a net gain of flood storage.

c. In fluvially dominated cases there is a minor increase in flood levels in the upper reaches of the Tideway that currently would already experience out of bank flooding during the scenarios modelled. Following further examination of the location of these increases in relation to the existing water levels, flood defence levels and landuse vulnerability, it is concluded that the increase is not significant in either flood risk or standard of protection terms.

15.5.28 Although the net effect is a gain in flood storage within the Tideway, analysis of the results has shown that this effect is spatially variable (depending on tidal and fluvial conditions) and some flow scenarios would result in marginally increased high tide levels in some locations and marginal decreased high tide levels in others.

15.5.29 For this reason a comparison has been made in this FRA of the maximum predicted changes in peak water level against the existing flood defence levels (Vol 3 Table 15.5.2). This compares changes in freeboard during the 1 in 200 year climate change event as a result of the proposed development.

15.5.30 The analysis shows that marginal increases in peak water levels would not result in overtopping of defences; but instead, results in a very small reduction in the available freeboard of the defences (a maximum of 5.8% for temporary works, and 3% for the permanent works).

15.5.31 Flood risk is a combination of the probability of a flood event occurring, and the consequence (or severity) if it did occur. For flood risk to be significantly increased there needs to be a significant increase in the probability and/or an increase in consequence (or severity). The analysis of peak water level changes against flood defence levels for both tidal and fluvially dominated scenarios shows no significant change in either the probability of flooding or the consequences if it did.

15.5.32 Assuming operation of the Thames Barrier, no person, property or parcel of land would be subject to a change in the probability or consequence of flooding when considering the 1 in 200 year tidal event and 1 in 500 year fluvial event when compared to the current situation. Therefore there is not considered to be a significant increase in flood risk and compensatory storage is not required for either the temporary or permanent works in the Tideway.

River walls

15.5.33 It is possible that tunnelling and other construction methods could lead to the settlement of river walls and flood defences (as well as other buildings and structures). The proposed design has been informed by consideration of settlement and the alignment and methods used have been selected to minimise the risk of settlement as far as possible.

15.5.34 Where shaft construction and tunnelling at specific sites has the potential to result in settlement of flood defences, these effects are given consideration in in each site specific FRA. However, the tunnel route has the potential to affect flood defence assets outside the project site boundaries. These have been identified in a separate table in Vol 3 Appendix M.2 which identifies each potential defence asset on a project-wide basis as well as existing flood defence height, potential settlement (based on information provided by Thames Water) and the implications of this in relation to freeboard. The freeboard summary in Vol 3 Appendix M.2 has also included the potential cumulative effect of both the unmitigated settlement and peak water level changes as a result of the foreshore works as summarised in Vol 3 Table 15.5.1and Vol 3 Table 15.5.2.

15.5.35 The freeboard summary provided in Vol 3 Appendix M.2 shows that approximately one third of the flood defence assets along the main tunnel route could potentially fall below the statutory flood defence level as a result of the combined effect of unmitigated settlement and peak water level changes.

15.5.36 In view of the uncertainty inherent in the settlement predictions, the proposed approach to settlement mitigation is a ‘monitor and mitigate’ approach. Under this approach, defence assets, which are considered to be at risk of settlement, would be monitored during construction and if their level is reduced they would be built back up to their existing levels. With this strategy in place no adverse residual effects of settlement are anticipated. Further information on the asset protection process is provided in the *Settlement Information Paper* (see Vol 1 Appendix C).

15.5.37 An appropriate monitoring and mitigation strategy would be developed in agreement with the EA and the asset owners.

15.5.38 A route-wide assessment of the effects of predicted construction-induced ground movement on the structural integrity of flood defences has been undertaken by Thames Water. This assessment included flood defence assets within the zone of influence of the main tunnel, connection tunnels and shafts. Flood defence assets within the zone of influence of proposed construction sites were assessed in the same way alongside consideration of other impacts, and these are discussed separately in the site-specific flood risk assessments.

15.5.39 The route-wide assessment identified a small number of assets as being in very poor condition. It is expected that remediation works to these structures may be undertaken by others prior to the start of the tunnel construction, in which case the assets would be re-assessed following these works. If this is not the case, the condition of the asset would be recorded prior to construction and a risk management strategy would be developed in agreement with the asset owner.

15.5.40 Apart from assets in very poor condition, the assessment found that tie-rod stress increase in tied structures is the only structurally significant issue that may result from ground movement. Potentially significant tie-rod[iii] stress increases were highlighted for a small number of assets.

15.5.41 Detailed assessments would be carried out by the contractor and proposals for any required mitigation works would be confirmed prior to the tunnelling works.

Scour assessment

15.5.42 Both the temporary and permanent works have the potential to influence scour and /or deposition rates within the river and affect river structures including flood defences.

15.5.43 The Thames Tideway Tunnel project would include a number of temporary and permanent works located within the River Thames itself. A scour summary study (Vol 3 Appendix L.3) has been completed to outline the potential magnitude of scour of the riverbed associated with the works. The sites that were included in the scour assessments were:

a. Putney Embankment Foreshore
b. Albert Embankment Foreshore
c. Chelsea Embankment Foreshore
d. Kirtling Street
e. Heathwall
f. Blackfriars Bridge Foreshore
g. King Edward Memorial Park Foreshore
h. Chambers Wharf
i. Victoria Embankment Foreshore
j. Carnwarth Road

15.5.44 At each of these sites, potential scour has been assessed for operation and construction using currently available data including bed grab

[iii] Tie-rod stress analysis aims to determine the likely tie-rod stress change as a result of differential ground movement between a river wall and its anchor, caused by tunnel construction.

samples, detailed bathymetry survey, design layouts and available flow modelling.

Construction

15.5.45 Results from the scour summary report have been used to inform the *Scour monitoring and mitigation strategy* (see Vol 3 Appendix L.4) for temporary works in the foreshore. In view of the limited scour predicted at most sites and the uncertainty over the predictions, the proposed approach to scour during construction outlined in the *Plan* is a 'monitor and mitigate' approach. Under this approach, any potential scour development during construction would be monitored and protective measures would only be provided when an appropriate trigger level is reached. This approach would limit the scour protection to areas where it is required and thus help minimise encroachment on habitats and help maintain existing channel profiles.

Operation

15.5.46 Results from the scour summary report have been used to inform the approach for permanent works in the foreshore. The approach to scour protection for the permanent works sites is outlined in the *Engineering Design Statement*, which accompanies the application, and the areas for the potential extent of scour protection for permanent works are outlined on the parameter plans for each foreshore site (see Sections 1 in Vols 4 to 27 separate volumes of figures). In contrast to the approach taken during construction and given the design life of the development, a proactive approach has been defined, which specifies scour protection as part of the design for the permanent works.

15.5.47 The effect of the permanent works on scour at third party structures would be monitored for a one year period in a similar way to that defined for the construction phase. Given that the permanent works are smaller than the temporary works it is unlikely that further scour effects would occur, which have not manifested themselves during the construction phase. However in the event that the monitoring identifies a need for new or additional protective works to an existing structure, these works would be agreed with the owner of the structure and the relevant consents obtained as necessary.

15.5.48 A cumulative effect of scour, in terms of deposition of sediment has been assessed in Section 14 of this volume.

Surface water flood risk

15.5.49 The surface water flood risks arising at each site and also those generated by any increase in hard standing at the sites have been assessed in each of the site specific volumes.

15.5.50 The design principle (see *Design Principles report Section 3 in* Vol 1 Appendix B) which requires the incorporation of SuDS and other attenuation measures across the project as outlined in site specific assessments would ensure there is no are no project-wide effects from surface water both to and from the development. There would therefore be no increase in flood risk from this source as a result of this development, and it has not been considered further in this project-wide assessment. An assessment of surface water project-wide considerations is provided in Section 14 of this volume.

Groundwater flood risk

15.5.51 The groundwater flood risks have been assessed in each of the site specific volumes and project-wide groundwater effects are being considered in Section 13 of this volume. Because of the depth of the tunnel, no interaction is anticipated between the tunnel construction and operation and groundwater flooding at the project-wide scale. Groundwater flood-risk is therefore assessed only in relation to works at the individual main tunnel and CSO sites (see respective main tunnel and CSO site assessments, Vols 4 to Vol 27). Therefore there are not considered to be any project-wide effects from groundwater flood risk both to and from the development and this flood source has not been considered further in this project-wide assessment.

Sewers flood risk

15.5.52 The Beckton and Crossness Sewage Treatment Works (STW) sewer catchment model (Thames Water, 2012)[7] used to assess the CSO performance has also been used to assess the effect of the tunnel on upstream sewer flooding risk. The predicted change in flood risk between the baseline case and Thames Tideway Tunnel project in 2020s has been assessed. The baseline case comprises the STW Improvements and Lee Tunnel in 2020s[iv]. The Thames Tideway Tunnel project is part of the London Tideway Improvements (LTI) programme which includes the Works Improvements and the Lee Tunnel.

15.5.53 A severe design storm with a 15 year return across the Beckton and Crossness STW catchment has been used. Normally such a storm would only be applied over a limited area with a less severe storm over the rest of the catchment, simulating normal storm conditions. The test case therefore represents an unusual storm, with a return period of approximately 35 years.

15.5.54 The maximum water level at each model node (manhole) during this design storm is compared between the baseline model and the LTI model. There are 5,513 comparable nodes in the model. Freeboard is the difference between the maximum simulated water level and ground level at the manhole node. Manholes with more than three meters freeboard are considered to be at a low risk of sewer flooding as these levels are generally considered to be lower than local basement connections.

15.5.55 This analysis has shown that with the Thames Tideway Tunnel project in operation, there is no increase in sewer flooding risk over the baseline. The model shows that there are no manhole nodes in the sewer catchment model that reduces freeboard by more than 100mm or changes

[iv] The Lee Tunnel and the sewage works upgrades proposed at Mogden, Beckton, Crossness, Long Reach and Riverside sewage treatment works (STWs) would be operational by the time construction of the Thames Tideway Tunnel project commences.

the risk category when compared to the baseline case. Some manhole nodes (76) have an improvement, moving from within three meters of freeboard to more than three meters of freeboard. Vol 3 Table 15.5.3 summarises the sewer flooding risk comparison.

Vol 3 Table 15.5.3 Flood risk – Sewer Flooding Risk Comparison for the test 15 year design storm

	No. of Modelled Manhole Nodes		
Modelled Node Risk Category	**STW Improvement and Lee Tunnel 2020s (Baseline)**	**London Tideway Improvements – 2020s**	**Difference London Tideway Improvements over Baseline**
Risk of Flooding **Less than 3m freeboard**	3262	3186	-76 (less risk)
Low Risks **More than 3m freeboard**	2251	2327	76 (improved)
Total Modelled Manhole Nodes	5513	5513	15.5.56

Design measures

15.5.57 When the tunnel is taken out of service for maintenance (in itself a rare event, as this is only planned for once in 10 years), and should this coincide with other rare events such as an extreme storm and high tide, some small localised increase in level may briefly occur in the vicinity of the interception points. The design would minimise this as far as practicable.

15.5.58 During construction some diversionary work would be necessary, but the diversions, temporary flumes or other measures would be designed to minimise the impact on flow.

Artificial source flood risk

15.5.59 The flood risks from artificial sources have been assessed in each of the site specific volumes. No project-wide effects from artificial sources both to and from the development have been identified such as large scale reservoirs that would affect more than one site and therefore this flood source has not been considered further in this project-wide assessment.

Residual risk

15.5.60 The residual risk to the development is the risk that remains after all design measures have been incorporated.

15.5.61 Much of the proposed development lies within tidal and fluvial flood zones protected from flooding by existing or new flood defences. Therefore these would be defended from tidal and fluvial flooding to the statutory level, but floodwaters could inundate the Sites in the event of overtopping (for example if the Thames Barrier fails to close during a tidal event) or a failure of the flood defences as a result of a breach.

Operational implications

15.5.62 The consequence of a breach or failure of flood defences could involve loss of power, automatic control and system monitoring functions at the site or sites affected. Any local air management equipment present at the site(s) could also fail due to loss of power, control and, potentially, by flooding of filter media.

15.5.63 Loss of these local functions would not compromise the long term operation of the tunnel as flow into the tunnel could be controlled, if required, by manual operation of actuated penstocks while electro mechanical systems are serviced or replaced. It is envisaged that most of the affected plant could be serviced or replaced and returned to automatic operation within a few weeks of the flood subsiding.

15.5.64 Flooding of the tunnel itself would not create conditions dissimilar to those under which the tunnel is designed to operate and would not compromise the long term operation of the tunnel. It is envisaged that following a flood event the tunnel would be emptied at Beckton STW by pumping to either the sewage treatment works or directly to river, depending on the sewage content and the salinity of the captured floodwaters.

15.5.65 No additional flood protection measures are proposed to defend against the residual risk because:

a. the risk of breach in flood defences is low

b. for damage to the equipment would not create a safety hazard locally, and is highly unlikely to affect the tunnel system such as to cause a hazard or create operational problems elsewhere

c. recovery from flood could be achieved relatively quickly as most equipment likely to be damaged is “off the shelf”.

15.5.66 By contrast, to defend against residual risk would require equipment to be raised above possible flood levels and would:

a. make operation and maintenance more difficult

b. be disproportionate to cost of repair

c. be unacceptable aesthetically particularly on public realm/heritage sites such as Victoria Embankment Foreshore and Putney Embankment Foreshore.

15.5.67 Therefore taking the operational implications into account it is considered that the consequence of a breach or failure of flood defences would not compromise the long term operational function of the tunnel, and would not increase flood risk elsewhere and therefore no additional measures to defend against residual risk are proposed.

Design measures

15.5.68 All construction works would be controlled by the *CoCP Part A and Part B* which highlights the residual risk and requires planning measures to mitigate the risk to be in place prior to construction.

Climate Change

15.5.69 Climate change is expected to have a major influence on the potential for future flooding. The latest United Kingdom Climate Projections (UKCP09)[8] were released in July 2009 and provide information on how the UK's climate is likely to change in the 21st century, as it responds to rising levels of greenhouse gases in the atmosphere.

15.5.70 Predicted impacts due to climate change include, inter alia, an increased frequency of heavy, intense precipitation, both in winter and in summer thunderstorms, increase in peak river flows and a rise in sea level affecting tidal areas. These impacts have implications for flood risk, surface water attenuation and the tunnel design as explained below.

15.5.71 The EA established the Thames Estuary 2100 (TE2100)[9] project with the aim of developing a long-term flood risk management plan for London and the Thames Estuary. The plan suggests the height of the tidal Thames flood defences could be raised in the future to mitigate the impact of climate change. Any new river walls at the Thames Tideway Tunnel project foreshore sites have been designed so that it is possible to raise them at a later date taking into account the requirements of the TE2100 project.

15.5.72 When determining site specific preliminary surface water attenuation requirements an allowance for climate change has been made in the rainfall calculations (see methodology in Vol 2 Section 15).

15.5.73 The design of structures located within fluvial floodplains has been informed by modelled flood water levels which include an allowance for the impact of climate change (see methodology in Vol 2 Section 15).

15.5.74 With the above design measures in place, the project would be resilient to the potential impacts of climate change.

15.6 Exception Test

Part a) Sustainability benefits

15.6.1 For the Exception Test part a) to be passed 'it must be demonstrated that the project provides wider sustainability benefits to the community that outweigh flood risk' as stated in the NPS.

15.6.2 The Waste Water NPS establishes a clear national need for the Thames Tideway Tunnel project. A sustainable long term solution is required to address the unacceptable levels of untreated sewage which are discharged into the tidal Thames and which have significant environmental, social and economic effects. The Government considers that detailed investigations have confirmed the case for a Thames Tideway Tunnel project as the preferred solution.

15.6.3 The Waste Water NPS states that ''the Thames Tideway Tunnel project is considered to be an infrastructure scheme of national significance for a number of reasons:

a. it is essential to meet the ecological water quality objectives of a major river of national importance

b. it is essential to reduce the risk of human health impacts

c. it is essential to reduce aesthetic impacts

d. it is essential to meet statutory requirements.''

15.6.4 Project need is considered in further detail within the *Project Needs Report* (Thames Water, 2012)[10] and in the *Planning Statement,* which accompanies the application. These provide additional detail in respect of the above reasons and so provide additional support in respect of part a) of the Exception Test.

15.6.5 Part a) is further supported by the *Sustainability Statement,* which accompanies the application*.* The *Sustainability Statement* assesses the project against the key environmental, social and economic themes and objectives, demonstrating how a sustainable outcome would be achieved by the project. It also describes how the project has been developed with regard to sustainability during design development, whereby a shorter tunnel solution has been adopted, limiting the number of sites required in construction, and reducing materials, energy and excavated material.

15.6.6 The flood risk summary from the *Sustainability Statement* is stated as follows:

15.6.7 "**Change adaptation and flood risk:** Maximise resilience and adaptability to change, and take account of flood risk in the design of sites. The project would address the frequent discharge of combined sewage into the tidal Thames. For the project to be sustainable, it must be resilient to future change, including an increase in population and a changing climate. The system design draws from future climate change projections and population trends, and can meet these challenges with limited adaption measures, whilst continuing to meet the Projects CSO management objectives. This *Sustainability Statement* also draws from the *Environmental Statement*, to demonstrate how the design of sites takes into account flood risk.''

15.6.8 Therefore, taking into account the Waste Water NPS which states the project is needed on sustainability grounds, the *Project Needs Report* , the *Sustainability Statement* and the *Planning Statement,* the project is considered to provide wider sustainability benefits to the community that outweigh the flood risks and therefore it is considered to pass part a) of the Exception Test.

Part b) Redevelopment of previously developed sites

15.6.9 For the Exception Test part b) to be passed 'the project should be on developable previously-developed land or, if it is not on previously developed land, that there are no reasonable alternative sites on developable previously developed land'.

15.6.10 An extensive site selection process has been undertaken for the project as explained in Vol 1 Section 3 and in full in the *Final Report on Site Selection Process*, which accompanies the application*.* The methodology was subject to consultation with stakeholders and considers a range of environmental, property, community, engineering and planning factors relevant to the suitability of sites.

15.6.11 It can be observed that out of a total of twenty-four proposed developed sites, fifteen are located on previously-developed land. This is a greater number than in earlier stages of consultation. It can therefore be seen that, in tandem with other relevant factors, directing development towards previously development land has been a relevant factor in site selection.

15.6.12 For those sites not on previously-developed land the *Final Report on Site Selection Process* can be referred to for information on the range of relevant factors as to the selection of that site. For example, existing CSOs are generally located at the river wall where land is frequently occupied by built heritage, community facilities, employment uses or residential uses. In a minority of cases such factors have, individually or in combination with other relevant factors in the site selection process, resulted in an undeveloped location being found more suitable. In the meaning of the Exception Test part b, such a site would not be a 'reasonable alternative'.

15.6.13 Part b) of the Waste Water NPS Exception Test has therefore been met.

Part c) Flood risk assessment

15.6.14 For the Exception Test part c) to be passed 'a FRA must demonstrate that the project will be safe, without increasing flood risk elsewhere, and, where possible, will reduce flood risk overall' as stated in the Waste Water NPS.

15.6.15 This project-wide FRA has considered all sources of flood risk throughout the project area. No project-wide risks from surface water, ground water, sewers or artificial sources have been identified

15.6.16 The hydraulic modelling has demonstrated that the project would have no significant impact on water levels or freeboard. The development in the foreshore provides an increase in the available storage at certain points of the tide by restricting the flow tide up the River Thames and no related mitigation is required or proposed for the foreshore works.

15.6.17 Flood risk from surface water would be reduced as a result of the project. At sites that are not discharging surface water to tidal watercourses, the Mayor's essential standard would be met for the management of surface water, reducing the rate and volume of runoff and hence reducing flood risk.

15.6.18 All potential effects relating to settlement and scour would be managed through onsite mitigation to ensure there is no decrease in the standard of flood defence. The foreshore sites would include new flood defence walls as part of the permanent site boundary, offering an improved condition or maintained flood defence condition at all sites with allowances made for future increases in the heights of defence in accordance with the TE2100 project.

15.6.19 This project-wide FRA demonstrates that the proposed development would therefore be considered appropriate, flood risk would be managed through appropriate design measures and the development would not lead to an increase in flood risk on the wider surrounding area. Flood risk improvements would be provided for most of the foreshore sites where new flood defences would be constructed as part of the permanent works. Part c) of the Waste Water NPS Exception Test has therefore been met.

15.7 Summary of significant effects at all sites

15.7.1 No significant effects are anticipated at any Thames Tideway Tunnel project sites, therefore no mitigation measures have been proposed.

References

[1] DEFRA. *National Policy Statement for Waste Water* (March, 2012).

[2] Communities and Local Government. *National Planning Policy Framework* (March, 2012).

[3] [3] Greater London Authority. *London Plan – Spatial development strategy for Greater London* (2011).

[4] Great Britain. *Thames River Protection of Floods Amendment Act 1879* London*,* The Stationery Office.

[5] Communities and Local Government. *Technical Guidance to the National Planning Policy Framework* (March 2012).

[6] HR Wallingford. *Combined Sewer Overflow Foreshore Works Tidal Flood Modelling – Overall impact upon the Tidal Thames (*November, 2011).

[7] Thames Water. *Draft Technical Memorandum – Tunnel Availability Flood Risk Assessment (Ref 100-CN-MDL-TTSCH-000001-AA)* (May 2012).

[8] UK Climate Change Projections, *UK Climate Impact Programme 2010.* Available at: http://ukclimateprojections.defra.gov.uk/

[9] Environment Agency. *Thames Estuary 2100 Plan.* (November 2012).

[10] Thames Water. *Project Needs Report*. Available at: http://www.thamestunnelconsultation.co.uk/document-library/catalogue-view/?c=1-the-need-for-the-thames-tunnel. Accessed 31 August 2012.

This page is intentionally blank

Thames Water Utilities Limited
Clearwater Court, Vastern Road, Reading RG1 8DB

DCO-DT-000-ZZZZZ-060203