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Contents

List of Abbreviations

AEP	Annual Exceedance Probability
AOD	Above Ordnance Datum
BGS	British Geological Survey
BSI	British Standards Institute
CEMP	Construction Environmental Management Plan
CIRIA	Construction Industry Research and Information Association
DMRB	Design Manual for Roads and Bridges
EA	Environment Agency
EIA	Environmental Impact Assessment
FRA	Flood Risk Assessment
HGV	Heavy Goods Vehicle
LLFA	Lead Local Flood Authority
NPPF	National Planning Policy Framework
NSIP	Nationally Significant Infrastructures Project

OS	Ordnance Survey
PEIR	Preliminary Environmental Information Report
PINS	Planning Inspectorate
PPG	Planning Policy Guidance
SFRA	Strategic Flood Risk Assessment
SPZ	Source Protection Zone
SuDS	Sustainable Drainage Systems
TBM	Tunnel Boring Machine
UK	United Kingdom
WFD	Water Framework Directive

Glossary of Terms

Annual chance	Floods are described according to an 'annual chance'. Meaning the chance of a particular flood occurring in any one year. This is directly linked to the probability of a flood. For example, a flood with an annual chance of 1 in 100 (a 1 in 100 chance of occurring in any one year), has an annual probability of 1%.
Aquifers	An underground layer of water-bearing permeable rock
Breach scenario	A Breach scenario is when a flood defences overtops or fails
Core Strategy	The Core Strategy sets out the vision, key objectives and strategic planning policies for the area.
Dewatering	The process of removing groundwater from an aquifer
Flood gates	Flood gates used to control water flow in flood barriers, reservoir, river, stream, or levee systems.
Floodplain compensation	An artificially excavated, hydraulically equivalent volume of floodplain storage sufficient to offset a reduction in floodplain storage resulting from filling or construction within the local regulatory floodplain.
Solid (bedrock) geology	Consolidated material that underlies superficial geology; bedrock

Source Protection Zone	An Environment Agency designation to identify and protect groundwater supplies. There are 3 zones – Inner (defined as the 50 day travel time from any point below the water table to the source), Outer (defined by a 400 day travel time from a point below the water table) and Source Catchment (defined as the area around a source within which all groundwater recharge is presumed to be discharged at that source)
Superficial geology	Unconsolidated material, usually recent, occurring at the Earth's surface (as distinct from solid geology)

SUMMARY

1. The Scheme – known as the Silvertown Tunnel – involves the construction of a twin bore road tunnel providing a new connection between the A102 Blackwall Tunnel Approach on Greenwich Peninsula (London Borough of Greenwich) and the Tidal Basin roundabout junction on the A1020 Lower Lea Crossing/Silvertown Way (London Borough of Newham. The Silvertown Tunnel would be approximately 1.4km long and would be able to accommodate large vehicles including double-deck buses. The Boord Street footbridge over the A102 would be replaced with a pedestrian and cycle bridge.
2. The design of the tunnel would include a dedicated bus/coach and HGV lane, which would provide opportunities for TfL to provide additional cross-river bus routes.
3. Main construction works would likely commence in 2018 and would last approximately 4 years with the new tunnel opening in 2022/23. The main site construction compound would be located at Silvertown to utilise Thames Wharf to facilitate the removal of spoil and delivery of materials by river. A secondary site compound would be located adjacent to the alignment of the proposed cut and cover tunnel on the Greenwich peninsula.
4. Hyder Consulting (UK) Limited ('Hyder') has been commissioned by TfL to undertake a Flood Risk Assessment (FRA) in support of the proposed Scheme, which comprises a twin bored tunnel beneath the River Thames and linking portals at the northern and southern ends of the tunnel. This FRA assessment outlines the risk of flooding to both the temporary construction worksite areas and the permanent elements of the operational tunnel.
5. This FRA has been undertaken in accordance with the requirements of the National Planning Policy Framework (NPPF) and specific guidance provided by the Environment Agency. The FRA methodology has involved assessing risk to the Scheme from all potential sources of flooding. All available flood risk data has been reviewed. This data has been collected from the

Environment Agency and Lead Local Flood Authorities. The assessment has also been informed by the results of bespoke hydraulic modelling undertaken to quantify flood conditions local to the Scheme under a Thames defence breach scenario.

6. Measures are recommended to ensure appropriate consideration of the risk of flooding is taken and the FRA sets out how the Scheme will be safe with respect to flooding during its life time and will not increase the risk of flooding to other sites.
7. The southern portal is located wholly within Flood Zone 3, in the 1 in 200 year floodplain of the River Thames. The majority of the Northern portal is also located in Flood Zone 3 but a small area is located in Flood Zone 2, in the 1 in 1000 year floodplain. Both the northern and southern portals are classed as being in an ‘Area Benefitting from Defences’ (ABD), which reduces the actual flood risk to the Scheme.
8. The Scheme is classed as ‘Essential Infrastructure’ by the NPPF. Therefore the Scheme needs to pass the Sequential and Exception tests. It is considered that London Borough of Newham and Royal Borough of Greenwich can demonstrate the satisfaction of the Sequential Test since it would not be possible to locate the Scheme elsewhere in Flood Zone 1.
9. With regard to satisfaction of the Exception Test, all sources of potential flood risk to the Scheme have been examined. The proposed Scheme, which for the purposes of this FRA includes both the temporary construction worksite areas and the permanent tunnel elements, is not perceived to be at significant risk of flooding from groundwater, sewers or artificial sources. The main source of flooding to the Scheme is associated with breach of existing defences in combination with extreme tide levels. Flood conditions have been defined using Environment Agency data and will be refined using the results of bespoke breach modelling, which is currently in progress.
10. Based on existing available information, it is considered that the Scheme is generally at low risk of flooding from surface water, with locally higher areas of risk where existing local drainage infrastructure is in poor condition, or there

are depressions in the topography. It is recommended that the Scheme design mitigates this risk by improving drainage infrastructure where it is currently failing in the northern worksite area. A strategy for managing surface water drainage for the Scheme has been developed by Atkins. The strategy is based on the principals of providing treatment and attenuation of surface water runoff prior to discharge to watercourses and the existing sewer network.

11. A Flood Warning and Evacuation Plan has been produced for construction and the operational life time of the Scheme that links into the Environment Agency's advanced flood warning system.

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1. INTRODUCTION

1.1 Background

1.1.1 The Scheme – known as the Silvertown Tunnel – involves the construction of a twin bore road tunnel providing a new connection between the A102 Blackwall Tunnel Approach on Greenwich Peninsula (London Borough of Greenwich) and the Tidal Basin roundabout junction on the A1020 Lower Lea Crossing/Silvertown Way (London Borough of Newham. The Silvertown Tunnel would be approximately 1.4km long and would be able to accommodate large vehicles including double-deck buses. The Boord Street footbridge over the A102 would be replaced with a pedestrian and cycle bridge [add this to end of previous para. in the short version].

1.1.2 New portal buildings would be located close to each portal to house the plant and equipment necessary to operate the tunnel, including ventilation equipment.

1.1.3 The introduction of free-flow user charging on both the Blackwall and Silvertown Tunnels would play a fundamental part in managing traffic demand and support the financing of the construction and operation of the Silvertown Tunnel.

1.1.4 The design of the tunnel would include a dedicated bus/coach and HGV lane, which would provide opportunities for TfL to provide additional cross-river bus routes.

1.1.5 Main construction works would likely commence in 2018 and would last approximately 4 years with the new tunnel opening in 2022/23. The main site construction compound would be located at Silvertown to utilise Thames Wharf to facilitate the removal of spoil and delivery of materials by river. A secondary site compound would be located adjacent to the alignment of the proposed cut and cover tunnel on the Greenwich peninsula.

1.1.6 Hyder Consulting (UK) Limited ('Hyder') has been commissioned by TfL to undertake a FRA in support of the proposed new road tunnel, which is hereinafter referred to as the Scheme[1].

1.1.7 The Scheme, including temporary construction worksites and the approaches to the operational tunnel, is shown to lie within Flood Zone 3, and in accordance with the NPPF[2] this FRA has been prepared to accompany the application for Development Consent (DCO application).

1.2 Aims and Objectives

1.2.1 The aim of this FRA document is to satisfy the requirements of the NPPF and Environment Agency in relation to development and flood risk.

1.2.2 Specific objectives of this FRA are to:

- Assess the Scheme against the requirements of the NPPF.
- Assess whether the Scheme has taken appropriate consideration of the risk of flooding from all potential flood sources.
- Detail how the Scheme will be safe with respect to flooding during its life time and will not increase the risk of flooding to other sites.

1.3 Terminology

1.3.1 Flood risk is a product of both the likelihood and consequences of flooding. Throughout this document, flood events are defined according to their likelihood of occurrence. Floods are described according to an 'annual chance', meaning the chance of a particular flood occurring in any one year. This is directly linked to the probability of a flood. For example, a flood with an annual chance of 1 in 100 (a 1 in 100 chance of occurring in any one year), has an annual probability of 1%.

[1] Throughout this report references to Scheme are referring to the current preferred engineering and environmental option that will be subject to further iteration through the design process.

[2] National Planning Policy Framework, March 2012, Department of Communities and Local Government

2. DEVELOPMENT INFORMATION

2.1 Location

2.1.1 The Scheme boundary comprises of an area of 25 hectares (ha) which includes the operational tunnel and temporary construction worksite areas to the north and south of the tunnel. This is illustrated in Figure 1. The Scheme spans the River Thames between the Greenwich Peninsula and Silvertown. The proposed tunnel will be bored beneath the River Thames and linked to portals on the north and south banks of river.

2.1.2 The Scheme lies within the unitary boundaries of the London Borough of Newham (to the north) and the Royal Borough of Greenwich (to the south).

2.1.3 In addition to the River Thames, the mouth of the River Lea (Bow Creek) is located adjacent to the western boundary of the northern construction compound for the Scheme.

Figure 1 Scheme location

2.2 Existing Development

Silvertown (North)

2.2.1 Development including a temporary construction worksite area and approaches to the operational tunnel on the north bank of the River Thames is situated within the London Borough of Newham. The northern red line area (Figure 1) is bounded in Silvertown by the Lower Lea Crossing, A 1011 Silvertown Way and the Docklands Light Railway viaduct and embankment.

Greenwich (South)

2.2.2 Development including temporary construction worksite areas and the approaches to the operational tunnel on the Southbank of the River Thames is situated along the A102 Blackwall Approach in the Royal Borough of Greenwich. The southern red line area (Figure 1) includes the area around Edmund Halley/Millennium Way and Cutter Lane, south of The O2 on the Greenwich Peninsula, and extends south within the confines of the Blackwall Tunnel Approach and West Parkside.

2.3 Proposed Scheme

2.3.1 Land take plans for the Scheme are included in Appendix 4.C Preliminary Engineering Report Maps, Plans and Drawings. TfL propose that the new tunnel would pass under the River Thames, with a corridor of land that has been safeguarded for this purpose.

Silvertown (North)

2.3.2 The areas of temporary and permanent land take associated with the Scheme to the north of the River Thames are shown in Figure 1. The northern tunnel entrance will link to a junction with the existing roundabout off Tidal Basin Road. This roundabout will connect the Silvertown Tunnel with the Lower Lea Crossing running west, and more local roads eastwards into the Royal Docks.

Greenwich (South)

2.3.3 The areas of temporary and permanent land take associated with the Scheme to the south of the River Thames are shown in Figure 1. Northbound traffic will enter the Silvertown Tunnel along a new spur road that branches off from the existing Blackwall Tunnel Approach road.

Southbound traffic leaving the tunnel will join the existing Blackwall Tunnel Approach southbound.

2.4 Topographic data

2.4.1 Land on both sides of the River Thames is gently undulating with ground levels in the region of 5mOD to 7mOD on the north side of the river and in the region of 3mOD to 7mOD on the south side of the River Thames. The bed of the River Thames is anticipated to have a gentle transverse dip ranging in elevation from 0mOD to -12mOD[3].

[3] Ground Investigation Desk Study Preliminary Sources Study Report May 2013 Mott MacDonald

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3. PLANNING POLICY CONTEXT

3.1 NPPF and Flood Risk

3.1.1 The NPPF and the 'planning practice guidance'[4] set out the Government's planning policies for England and how these are expected to be applied.

3.1.2 The principal aim of the framework is to contribute to the achievement of sustainable development. This includes ensuring that flood risk is taken into account at all stages of the planning process, avoiding inappropriate development in areas at risk of flooding and directing development away from those areas where risks are highest. Where development is necessary, it should be safe, without increasing flood risk elsewhere.

3.1.3 A site-specific FRA is required for proposals of 1ha or greater in Flood Zone 1; all proposals for new development (including minor development and change of use) in Flood Zones 2 and 3, or in an area within Flood Zone 1 which has critical drainage problems (as notified to the local planning authority by the Environment Agency); and where proposed development or a change of use to a more vulnerable class may be subject to other sources of flooding. The FRA should identify and assess the risks of all forms of flooding to and from the development and demonstrate how these flood risks will be managed so that the development remains safe throughout its lifetime, taking climate change into account.

3.1.4 Early adoption of and adherence to the principles set out in the NPPF can ensure that detailed designs and plans for developments take due account of the importance of flood risk and the need for appropriate mitigation, if required.

3.2 The Sequential and Exception Tests

3.2.1 The NPPF Sequential Test classifies proposed development into one of four Flood Zones, detailed in Table 3-1.

[4] http://planningguidance.planningportal.gov.uk/

Table 3-1 Flood Zones (Source: TGNPPF Table 1[5])

Flood Zone	Annual Probability of Flooding (%)	Corresponding Annual Chance of Flooding (1 in x)
1. Low Probability	Fluvial and Tidal <0.1%	>1,000
2. Medium Probability	Fluvial 0.1-1.0% Tidal 0.1-0.5%	1,000-100 1,000-200
3a. High Probability	Fluvial >1.0% Tidal >0.5%	<100 <200
3b. The Functional Floodplain	Fluvial and Tidal >5.0% *Starting point for consideration. LPAs should identify Functional Floodplain, which should not be defined solely by rigid probability parameters.	<20

3.2.2 The NPPF specifies that the suitability of all new development in relation to flood risk should be assessed by applying the Sequential Test to demonstrate that there are no reasonably available sites in areas with a lower probability of flooding that would be appropriate to the type of development proposed. The NPPF provides guidance on the compatibility of each land use classification in relation to each of the Flood Zones as summarised in Table 3-2.

Table 3-2 Flood Risk Vulnerability Classification (Source: TGNPPF Table 3[6])

Flood Zone	Essential Infrastructure	Water Compatible	Highly Vulnerable	More Vulnerable	Less Vulnerable
Zone 1	✓	✓	✓	✓	✓
Zone 2	✓	✓	Exception Test required	✓	✓
Zone 3a	Exception Test required	✓	×	Exception Test required	✓

[5] http://planningguidance.planningportal.gov.uk/
[6] http://planningguidance.planningportal.gov.uk/

Flood Zone	Essential Infrastructure	Water Compatible	Highly Vulnerable	More Vulnerable	Less Vulnerable
Zone 3b	Exception Test required	✓	×	×	×
Key: ✓ Development is appropriate × Development should not be permitted					

3.3 National Road and Rail Networks: National Policy Statement (NN NPS)

3.3.1 NN NPS for National Networks[7] sets out the need for, and Government's policies to deliver, development of nationally significant infrastructure projects (NSIPs) on the national road and rail networks in England. NN NPS supports NPPF and explains that essential transport infrastructure (including mass evacuation routes) is permissible in areas of high flood risk, subject to the satisfaction of the NPPF Exception Test.

3.3.2 The following are important considerations:

- Applicants for projects which may be affected by, or may add to, flood risk are advised to seek sufficiently early pre-application discussions with the Environment Agency, and, where relevant, other flood risk management bodies such as lead local flood authorities.
- If the Environment Agency has concerns about the proposal on flood risk grounds, the applicant is encouraged to discuss these concerns with the Environment Agency and look to agree ways in which the proposal might be amended, or additional information provided, which would satisfy these concerns, preferably before the application for Development Consent is submitted.
- Site layout and surface water drainage systems should cope with events that exceed the design capacity of the system, so that excess water can be safely stored on or conveyed from the site without adverse impacts.

[7] National Policy Statement (NPS) for National Networks, December 2014

- For construction work which has drainage implications there is the potential to increase flood risk. Therefore during construction, drainage should be considered and, if appropriate, controlled. This may include the use of sustainable drainage systems but could also include vegetation to help to slow runoff, hold back peak flows and make landscapes more able to absorb the impact of severe weather events.

3.3.3 This FRA has been prepared in close consultation with the Environment Agency, in order to agree assessment methodologies, gather flood risk data and agree approaches to flood risk mitigation.

3.4 The London Plan, Greater London Authority

3.4.1 The London Plan[8] is the overall strategic plan for London, and it sets out a fully integrated economic, environmental, transport and social framework for the development of the capital to 2036. The key London Plan policy regarding flood risk management is Policy 5.12, which seeks:

> *'to address current and future flood issues and minimise risks in a sustainable and cost effective way.'*

3.4.2 The policy requires planning decisions to:

> *'comply with the flood risk assessment and management requirements set out in the NPPF and associated Technical Guidance.'*

3.4.3 Policy 5.12 further states that:

> *'Development adjacent to flood defences will be required to protect the integrity of existing flood defences and wherever possible should aim to be set back from the banks of watercourses and those defences to allow their management, maintenance and upgrading to be undertaken in a sustainable and cost effective way.'*

[8] The London Plan, The London Mayor March 2015

3.5 CIRIA Development and Flood Risk: Guidance for the Construction Industry (C624)

3.5.1 CIRIA publication C624[9] provides guidance to developers and the construction industry on the implementation of good practice in relation to flood risk and the development process. The following should be important considerations:

- All developments, even those that lie outside Flood Zones 2 and 3, may lead to an increase in downstream flood risk due to increased runoff rates and volumes. Therefore, all new developments should be designed so that runoff from the development is considered and, if appropriate, controlled.
- Safe access to and from the development should be allowed for during a flood event and the above should be met for the lifetime of the development, including considerations for climate change.

3.6 London Borough of Newham SFRA and Royal Borough of Greenwich SFRA

3.6.1 Strategic Flood Risk Assessments (SFRA) were completed in 2011 for the London Borough of Newham[10] and Royal Borough of Greenwich[11]. SFRAs are intended to guide development decisions and allow Local Planning Authorities to apply the NPPF Sequential Test. An SFRA has specific objectives to:

- Provide a detailed and robust assessment of the extent and nature of the risk of flooding in the areas likely to accommodate significant growth in the next plan period.
- Ensure that local authorities meet their obligations under *Planning Policy Statement 25* (PPS25)[12], superseded by the NPPF in March 2012.

[9] Development and Flood Risk: Guidance to the Construction Industry (C624), 2004, CIRIA
[10] London Borough of Newham Strategic Flood Risk Assessment SFRA - Final Report, 2011 Capita Symonds
[11] London borough of Greenwich Strategic Flood Risk Assessment SFRA - Final Report, 2011 JBA
[12] Planning Policy Statement 25: Development and Flood Risk, updated March 2010, Communities and Local Government

3.7 Thames Estuary 2100 (TE2100)

3.7.1 The TE2100 Plan[13] sets out the strategic direction for managing flood risk in the Thames Estuary to the end of the century and beyond. The TE2100 Plan recommends what actions the Environment Agency and others will need to take to manage flood risk in the short term (next 25 years), medium term (the following 15 years) and long term (to the end of the century).

3.7.2 According to the TE2100 Plan the Scheme to the north of the River Thames is located in the Royal Docks policy unit and the recommended flood risk management policy (P4) is to take further action to keep up with climate change so that flood risk does not increase. To the south the Scheme is located in the Greenwich policy unit and the recommended flood risk management policy (P5) is to take further action to reduce flood risk beyond that required to keep pace with climate change. The Plan documents that there is a risk of urban drainage flooding in the Greenwich area, particularly where the capacity of the urban drainage system is limited. This risk is exacerbated by tide locking of outfalls. However, it is understood that local to the Scheme urban drainage flooding has not been a problem experienced in the past[14].

3.8 Environment Agency Flood Map

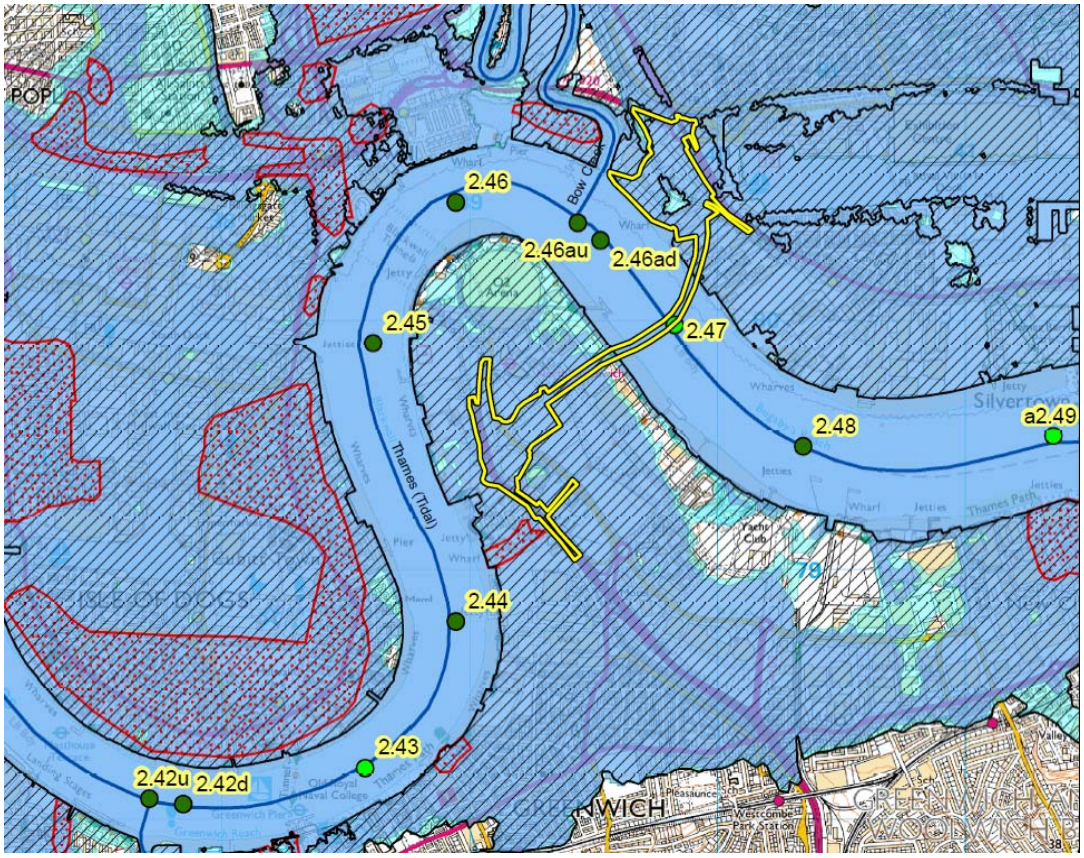
3.8.1 As part of this FRA ‘Flood Product 4’ and ‘Flood Product 8’ data requests were submitted to the Environment Agency. A ‘Flood Product 4’ data pack provided confirmation of flood zone classification, a detailed flood map, information about flood defences and historical flooding incidents and Environment Agency model output data such as predicted flood water levels (river and tidal) in the vicinity of the Scheme. The Flood Product 8 data pack provided a licenced copy of an Environment Agency hydraulic model of the River Thames which has been used as a tool to predicted flood conditions during a breach in the River Thames defences (as detailed in Section 5). The responses to these Flood Product requests are provided in Annex A.

[13] Thames Estuary 2100:Managing Flood Risk through London and the Thames Estuary (TE2100), November 2012, The Environment Agency

[14] Silvertown Tunnel Reference Design, Flood Risk Verification Report, July 2014, Atkins

3.8.2 An extract from the supplied Flood Map, applicable to the Scheme, is shown in Figure 2. The Environment Agency Flood Map shows that the southern portal is located wholly within Flood Zone 3, attributed to the 1 in 200 year floodplain of the River Thames. The majority of the northern portal is also located in Flood Zone 3, but a small area is located in Flood Zone 2 (in the 1 in 1000 year floodplain). The northern and southern portals of the Scheme are shown to benefit from existing flood defences, however, the section of tunnel which runs under the River Thames does not benefit from defences.

Figure 2 Environment Agency Flood map (Extract from Environment Agency Flood Product Data Response, Annex A)



3.8.3 In accordance with the NPPF, the development is classed as ‘Essential Infrastructure’ and as such the proposed development (within Flood Zone 3) will need to satisfy the requirements of the Sequential and Exception Tests for the development to be permitted.

3.8.4 For the Sequential Test to be passed, it needs to be demonstrated that within the London Borough of Newham and Royal Borough of Greenwich

there are no reasonably available alternative sites with a lower risk of flooding that could accommodate the Scheme.

3.8.5 For the Exception Test to be passed the following two criteria must be satisfied:

- it must be demonstrated that the development provides wider sustainability benefits to the community that will outweigh flood risk; and
- a site-specific FRA must demonstrate that the development will be safe for its lifetime taking account of the vulnerability of its users, without increasing flood risk elsewhere, and, where possible will reduce flood risk overall.

3.9 The Sequential Test

3.9.1 In January 2012, Newham Council published its Core Strategy[15]. Strategic Objective INF1 is to secure investment in strategic transport networks that will lever investment and regeneration into Newham. In 2014, the Royal Borough of Greenwich published its Core Strategy[16]. Policy IM3 is to support those transport Schemes that are critical to Greenwich's development.

3.9.2 The main aim of the Scheme is to reduce congestion at the Blackwall Tunnel, and improve the reliability and resilience of the wider road network. It is understood that there is regular congestion at the Blackwall Tunnel and journeys through the tunnel often take up to 20 minutes or more. The current level of demand on the Blackwall Tunnel exceeds its design and many heavy goods vehicles are unable to use the northbound tunnel due to height restrictions.

3.9.3 The Scheme aims to facilitate more predictable and reliable journey times by relieving congestion and providing additional road capacity. This will support growth and regeneration in surrounding areas. Therefore the Scheme is expected to contribute toward fulfilling Newham and the Royal Borough of Greenwich Councils Core Strategy Objectives INF1 and IM3.

[15] Newham's Local Plan, Core Strategy Adopted 2012
[16] Greenwich Local Plan, Core Strategy Adopted 2014

3.9.4 There is little flexibility in locating the Scheme given its aim of reducing congestion at the Blackwall Tunnel and the relatively extensive spatial coverage of Flood Zone 3 in both Boroughs. In addition, the land has been safeguarded by the Secretary of State for the construction of a river crossing at Silvertown.

3.9.5 It is therefore considered that Newham London Borough Council and Royal Borough of Greenwich Council can demonstrate satisfaction of the Sequential Test.

3.10 The Exception Test

3.10.1 For the same reasons above, it is considered that the Scheme can satisfy the first part of the Exception Test, having wider sustainability benefits to the community. The remainder of this document focuses on the second part of the Test, qualifying the actual risks of flooding to the Scheme, and making recommendations as to how the residual risk of flooding can be managed such that the Scheme can be considered safe throughout its lifetime, in line with the requirements of the Exception Test.

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4. FORMS OF FLOODING

4.1 Overview

4.1.1 This section assesses the proposed Scheme with reference to the forms of flooding as set out in Table 4-1 below.

Table 4-1 Forms of flooding

Source of Flooding	Description
1. Flooding from rivers	Flood water originating from a nearby watercourse when the amount of water exceeds the channel capacity of that watercourse
2. Flooding from the sea	High tides, storm surges and wave action, often acting in combination, flooding low-lying coastal land
3. Flooding from land	Flooding caused by intense rainfall exceeding the available infiltration and/or drainage capacity of the ground
4. Flooding from groundwater	Flooding caused when groundwater levels rise above ground level following prolonged rainfall
5. Flooding from sewers	Flooding originating from surface water, foul or combined drainage systems, typically caused by limited capacity of blockages
6. Flooding from reservoirs, canals and other artificial sources	Failure of infrastructure that retains or transmits water or controls its flow

4.2 Flooding from Rivers and Sea

4.2.1 As confirmed by the Environment Agency Flood map, the primary source of flood risk to the Scheme is tidal, arising from the River Thames. This source of risk is addressed in detail in Section 5.

4.2.2 To the south of the River Thames the Scheme is located within Flood Zone 3, in the 1 in 200 year floodplain of the River Thames. The exception is a small area within the operational tunnel boundary (see Figure 1) which is located in Flood Zone 2 in the 1 in 1000 year floodplain. Both the temporary worksite areas and the operational tunnel are shown to benefit from protection by flood defences.

4.2.3 The majority of the Scheme to the north of the River Thames is located in Flood Zone 3 but a small area in the temporary construction worksite boundary (Figure 1) is located in Flood Zone 2 in the 1 in 1000 year floodplain. Both the temporary worksite areas and the operational tunnel are shown to benefit from protection by flood defences, which reduce the actual flood risk to the Scheme.

4.2.4 It is therefore concluded that the Scheme is at low actual risk but high residual risk of flooding from rivers and sea. This form of flooding, including historical flood events, is discussed further in Chapter 5.

4.3 Flooding from Groundwater

4.3.1 Groundwater flooding occurs when water originating in aquifers reaches the surface, typically as a result of high groundwater levels caused by prolonged rainfall, obstructions to groundwater flow or rebound of previously-depressed groundwater levels.

4.3.2 With reference to public data provided by the British Geological Survey[17], it has been identified that the Scheme is underlain mainly by London Clay bedrock geology, overlain by superficial deposits of Alluvium clay, silt, sand and gravel formations. The Environment Agency 'groundwater' map[18] confirms that the Scheme is not located in a Groundwater Protection Zone. Superficial aquifers beneath the study area are classified as Secondary (undifferentiated), whilst the bedrock geology is largely classified as unproductive strata. Both the Greenwich SFRA[19] and Newham SFRA[20] state that there is no record of groundwater flooding in the area local to the Scheme.

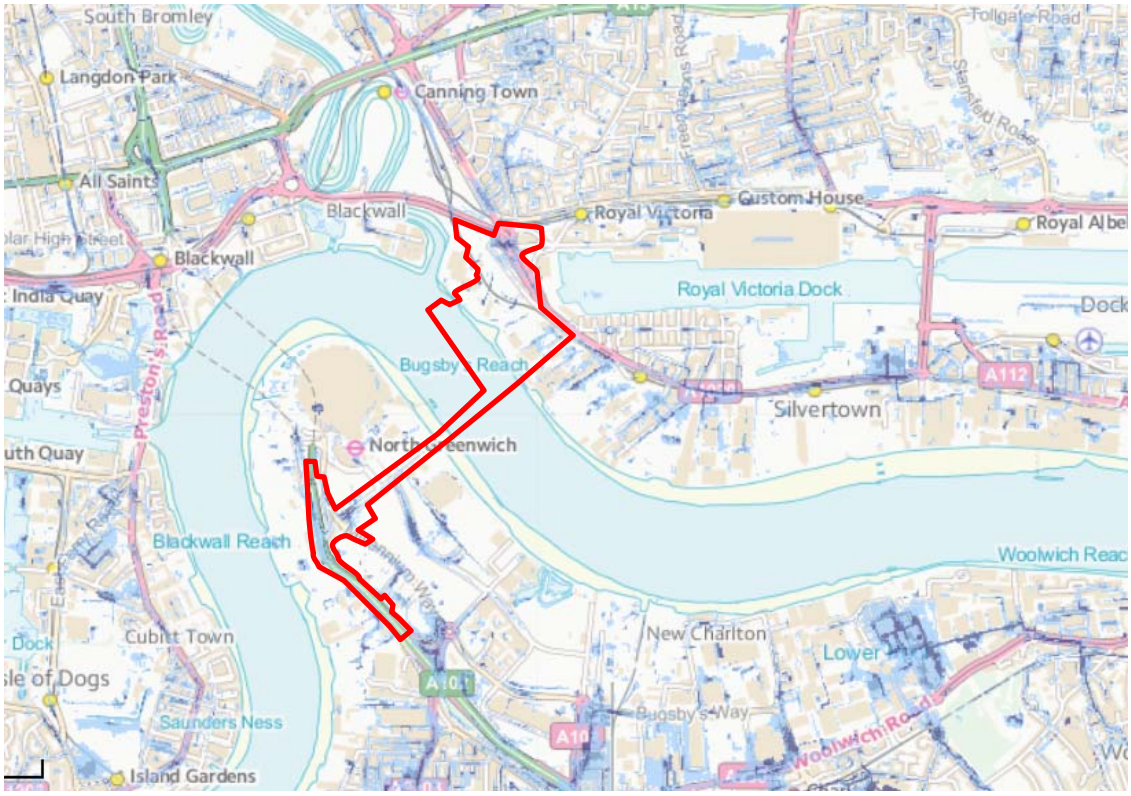
4.3.3 It is therefore concluded that the Scheme is considered at low risk from flooding from groundwater. This form of flooding is not therefore considered further in this FRA.

[17] British Geological Survey http://www.bgs.ac.uk/discoveringGeology/geologyOfBritain/viewer.html (linked accessed May 2013)
[18] 'What's In Your Backyard' Mapping, Environment Agency, http://maps.environment-agency.gov.uk/wiyby (linked accessed May 2013)
[19] London borough of Greenwich Strategic Flood Risk Assessment SFRA - Final Report, 2011 JBA
[20] London borough of Newham Strategic Flood Risk Assessment SFRA - Final Report, 2011 Capita Symonds

4.4 Flooding from Land

4.4.1 Flooding from land (often known as surface water flooding) occurs when extreme rainfall exceeds the infiltration or drainage capacity of the ground surface. This form of flooding can both pose a flood risk to the Scheme, from surface water runoff from off-site areas, and an increased flood risk to adjacent sites, as a result of runoff from the proposed Scheme (typically in the case of large sites).

Figure 3 Environment Agency Surface water Flood map (indicative Scheme location in red)



4.4.2 The Environment Agency provides information concerning the risk of surface water flooding, through their website[21]. According to the EA surface water maps, shown in Figure 3, the majority of the Scheme is located in an area of very low surface water flood risk (less than 1 in 1000 chance). There are some small isolated areas where the Scheme is at low (between 1 in 1000 and 1 in 100 chance), medium (between 1 in 100 and

[21] 'What's In Your Backyard' Mapping, Environment Agency, http://maps.environment-agency.gov.uk/wiyby (linked accessed May 2013)

1 in 30 chance) and high (greater than 1 in 30 chance) risk of surface water flooding, for example, in the south the road which forms the entrance of the operational tunnel is classed as at low risk of surface water flooding.

4.4.3 It is understood that currently the land that is to be occupied by the Scheme is fully covered by hardstanding material. Following completion of the Scheme there will be some landscaping which will reduce the amount of impermeable surface on site.

4.4.4 The EA have also advised of the presence of a number of operational waste handling sites that are to be occupied by the northern worksite area and have highlighted the poor state of the current drainage system that serves these sites.

4.4.5 The surface water catchment draining around the northern tunnel entrance is estimated to be 4,400m^2 and 11,900m^2 [22] drains around the southern portal.

4.4.6 The current drainage strategy centres on providing cut off drainage to prevent ingress of surface water runoff from the approach roads into the tunnel. A drainage sump would be located at the tunnel portals which would provide an intercept and storage facility for collected surface water run-off, as well as a reception chamber for water being pumped back from the low-point sump in the tunnel.

4.4.7 Surface water run-off from within the bored section of the tunnel would be collected via gullies or a combined drainage kerb system and collected in the sump, from where it would be pumped to the northern service building compound where an impounding foul sump would be provided. This would then ultimately discharge to sewer or to the River Thames. A second attenuation system, likely to take the form of oversized carrier drains or storage tanks, would be provided to store surface water runoff from the remaining catchment areas falling towards the tunnel entrances. A flow-control device would control the outfall rate into the portal sump from this attenuation system.

[22] Silvertown Tunnel: Highway Infrastructure conceptual design Recommendations, April 2013, Atkins

4.4.8 Based on existing available information, it is considered that the Scheme is generally at low risk of flooding from surface water, with locally higher areas of risk where existing local drainage infrastructure is in poor condition, or there are depressions in the topography. It is recommended that Scheme design mitigates this risk by improving drainage infrastructure where it is failing in the northern worksite area.

4.4.9 A strategy for managing surface water drainage arising from the Scheme has been developed by Atkins in consultation with the Environment Agency and Greater London Authority (GLA). The strategy is based on the principals of providing treatment and attenuation of surface water runoff prior to discharge to watercourses and the existing sewer network.

4.4.10 Areas to the north of the River Thames and the bored tunnel would discharge at attenuated rates to sewer and to the River Thames, via a small watercourse known as the Cut. To the south surface water discharges would be made at attenuated rates to the existing sewer network, as there is no suitable watercourse to receive drainage discharges.

4.4.11 The drainage strategy fulfils two of the three underlying principles of Sustainable Urban Drainage Systems (SUDS), namely seeking to improve the water quality of drainage discharge and to deal with surface water as close to source as possible, reducing flood risk. Constraints on applying SUDs techniques that are higher up in the drainage hierarchy set out in the London Plan, for example, using infiltration techniques, ponds and open water features, include high groundwater levels, land contamination legacy and space constraints. During the detailed design stage proposed discharge rates and destinations would be agreed with Thames Water, the Environment Agency and GLA and opportunities to maximise amenity and biodiversity associated with drainage infrastructure would be sought.

4.4.12 It is concluded that there would be no increase in surface water flood risk to third party lands during the operation of the Scheme.

4.5 Flooding from Sewers

4.5.1 Land within the Scheme boundary is currently served by a comprehensive network of highway drainage infrastructure and combined sewers that are maintained by Thames Water.

4.5.2 On the south side of the proposed tunnel existing drainage comprises kerb and gully systems that serve the A102 Blackwall Tunnel Approach

and the Tunnel Avenue road. These systems discharge directly into existing carrier drains that feed into the sewer network, to the north similar systems serve the North Woolwich road, Dock road, the A1020 Lower Lea Crossing and the A1011 Silvertown Way.

4.5.3 As outlined in Section 4.4, surface water runoff from the Scheme would discharge at attenuated rates to sewer or to the River Thames.

4.5.4 There are no known records of sewer flooding affecting the Scheme.

4.5.5 It is therefore concluded that the Scheme is considered at low risk from flooding from sewers and this form of flooding is not considered further in this FRA.

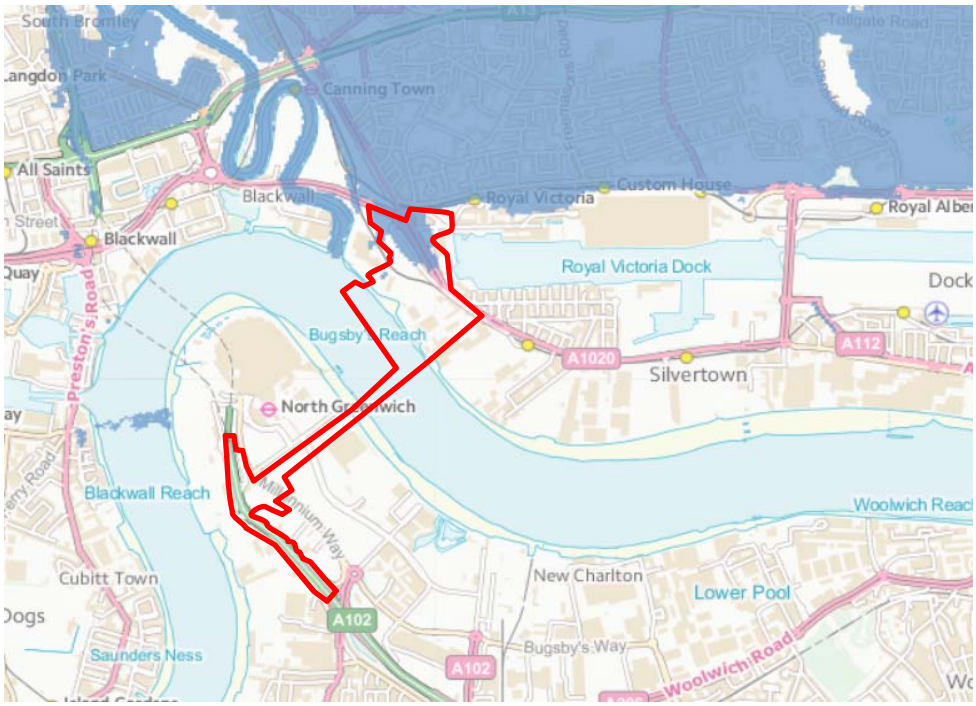
4.6 Flooding from reservoirs, canals and other artificial sources

4.6.1 The Environment Agency provides a map showing the maximum potential flood extent area, in the event that all reservoirs were to fail and release the water they hold. This map can be viewed online[23] and an extract is shown in Figure 4. The map shows that a small area of the Scheme to the north of the River Thames would be affected by a breach associated with the King George V and William Girling reservoirs. However, the Greenwich peninsula and southern portal is not at risk of flooding from reservoirs. Through the appropriate maintenance of reservoirs, flooding from a reservoir breach is extremely unlikely to happen. There are no canals or other artificial sources that would pose a flood risk in this area.

4.6.2 It is therefore concluded that the Scheme is at low risk from flooding from artificial sources. This form of flooding is therefore not considered further in this FRA.

[23] 'What's In Your Backyard' Mapping, Environment Agency, http://maps.environment-agency.gov.uk/wiyby (linked accessed May 2013).

Figure 4 Environment Agency Reservoir Inundation Flood map



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5. FLOOD RISK FROM RIVERS AND THE SEA

5.1 Environment Agency Flood Map

5.1.1 As outlined in Section 3.5, the Environment Agency Flood Map shows that to the south of the River Thames the Scheme is located wholly within defended Flood Zone 3 and the majority of the northern parts of the Scheme are located in defended Flood Zone 3, with a small area in Flood Zone 2.

5.2 Historic Flood Events

Silvertown (North)

5.2.1 The Environment Agency provided the extent of flooding recorded (Figure 2Figure) during the January 1928 flood event in the vicinity of the Scheme. No land within the Scheme boundary was flooded during this historical event. Additional Information provided by the Environment Agency states that the areas of Silvertown were subject to tidal flooding, due to a storm surge in the North Sea, on the night of the 31 January into the morning of 1 February in 1953. An approximate level in the River Thames at the time was 5.26m AODN. According to the Newham SFRA[24] the Northern portal also lies within the historical flood extent for the 1947 flood event.

Greenwich (South)

5.2.2 As shown in Figure 2, no land within the Scheme boundary experienced any flooding during the January 1928 event and the Scheme is located is approximately 400m north of the area flooded during the 1928 flood event. However, land within the Scheme boundary was affected by a flood event in 1953.

5.2.3 Since these historical events the Thames Barrage flood defence scheme has been put in place so similar flood events are very unlikely to be repeated.

[24] London borough of Newham Strategic Flood Risk Assessment SFRA - Final Report, 2011 Capita Symonds

5.3 River Thames flood levels

5.3.1 The location of the EA model nodes in the River Thames adjacent to the Scheme are illustrated in Figure 2. Predicted floodwater levels for the model nodes closest to the Scheme are outlined in Table 5-1 and current and proposed flood defence height are outlined in Table 5-2. The Environment Agency model results suggest that the Scheme is defended up to a 1 in 1,000 (0.1% annual chance) event. However the current defences are lower than the future 2100 predicted water levels, so if the defences are not raised to the proposed levels set out in the TE2100 plan, there is potential for future overtopping of the defences.

Table 5-1 Maximum EA predicted floodwater levels

	1 in 1000 Predicted Flood levels (mAOD)		
Model Node	**Present Day Water Level**	**Future 2065-2100 Water Level**	**Future 2100 Water Level**
2.44	4.69	5.18	5.67
2.45	4.68	5.17	5.66
2.46	4.67	5.16	5.65
2.46au	4.66	5.15	5.64
2.46ad	4.66	5.15	5.63
2.47	4.65	5.14	5.62
2.48	4.64	5.13	5.61

Table 5-2 Maximum EA predicted floodwater flows

	Current defence levels (mAOD)		**Future defence levels (mAOD)**	
Model Node	**Left bank**	**Right bank**	**Future 2065-2100**	**Future 2100**
2.44	5.18	5.18	5.70	6.20
2.45	5.18	5.18	5.70	6.20
2.46	5.18	5.18	5.70	6.20
2.46au	5.18	5.18	5.70	6.20

	Current defence levels (mAOD)		Future defence levels (mAOD)	
Model Node	**Left bank**	**Right bank**	**Future 2065-2100**	**Future 2100**
2.46ad	5.18	5.18	5.70	6.20
2.47	5.18	5.18	5.70	6.20
2.48	5.18	5.18	5.70	6.20

5.3.2 As illustrated by the data presented in Table 5-1 and Table 5-2 current defences (5.18m AOD) are generally sufficient to prevent overtopping to the year 2065, though with very little remaining freeboard.

5.3.3 During the 2065-2100 period defences will therefore need to be upgraded. A River Wall Structural Condition Survey (Appendix 16.D) for the lengths of river wall located within the red line boundary on both sides of the river has been conducted by Atkins. The findings show that the majority of the defences are classed as either a condition grade 3 or 4, where 1 is classed as very good and 5 is classed as very poor. The survey also concludes that all sections of river wall have the potential to support future raising. Methods could include raising existing concrete parapets, constructing concrete capping beams on existing sheet piles and constructing new flood walls directly onto existing concrete abutments.

5.3.4 On the Greenwich Peninsula, master planning for a significant redevelopment is currently underway and has been informed by a FRA[25]. The FRA includes the commitment to allow for the raising of existing river walls to 6.20mOD and incorporating a riverside walkway into the Masterplan. When constructed, this higher defence standard would benefit the wider peninsular, including the Silvertown Tunnel,

5.3.5 The Environment Agency inspect the defences twice a year to ensure that they remain fit for purpose and the design of the Scheme is such that there is enough space for plant to access the defence for maintenance purposes from the landward side.

[25] Greenwich Peninsula 2015 Masterplan, February 2015, Arup

5.4 Residual Risk

5.4.1 Although the risk of flooding to the Scheme, as a result of the overtopping of the existing defences, is low, there is a residual risk of flooding in the event of a breach of the defences.

5.4.2 The Environment Agency have provided outputs from a River Thames Tidal Breach modelling study, completed in 2012 the results of which are summarised below.

Silvertown (North)

5.4.3 A number of north bank breaches were simulated, coincident with a 1 in 200 flood event (0.5% annual probability). The breach location most relevant to the Scheme is located just south of the Royal Victoria Gardens. Predicted hazard, depth and velocity data are illustrated in Annex A. The data illustrate that, if a breach occurs on the north bank just south of the Royal Victoria Gardens, then the flood waters would not reach any part of the Scheme.

Greenwich (South)

5.4.4 The most relevant Environment Agency modelled breach location is located just east of the Thames Barrier. Predicted hazard, depth and velocity data are illustrated in Annex A. The data illustrates that, if a breach occurs on the south bank just east of the Thames Barrier, the majority of Scheme would be inundated with water. Resulting flood hazard is classed as ‘danger to most’, with depths of floodwater ranging between 0 – 0.25m, with higher depths (0.25 - 1m) located on the south westerly boundary.

5.4.5 Floodwater velocity is predicted to range between 0 - 0.3 m/s with higher velocities (0.3 - 1 m/s) located on the south westerly boundary.

5.4.6 Hyder is currently undertaking bespoke breach modelling to quantify flood conditions associated with north and south bank breaches at locations more local to the Scheme. This modelling work is scheduled to be completed in August 2015 and a technical note will document the findings, which will be appended to the final FRA, with a summary included within this report.

Hydrodynamic Modelling of the jetty structure

5.4.7 Hyder has undertaken an assessment of the impact of the proposed jetty structure on the north bank of the River Thames on the current hydrodynamics of the river. This has involved modelling the change in local currents due to the movement of water around the jetty piles in the MIKE21FM hydrodynamic modelling software.

5.4.8 The model results show that the inclusion of a straight or skewed jetty structure will very marginally reduce flow velocities around the jetty head and very marginally increase flow velocities at the jetty approaches. However no significant effects on the sediment transport regime is predicted and no discernible effects on water levels in the River Thames would occur.

5.4.9 Scour depths for the jetty piles were calculated under a range of tidal and river flow conditions and due to the propeller wash of vessels moored at the Silvertown jetty. The results showed that the maximum scour depth due to propeller wash with 1m underkeel clearance would be in the region of 2.6m, and that the appropriate armoured rock scour protection would be required.

5.5 Implications for the Scheme

5.5.1 The Scheme is defended up to a ‘present day’ 1 in 1000 year flood event. A River Wall Structural Condition Survey (Appendix 16.D) has indicated that it would be feasible to raise existing defences to the required TE2100 defence standard. Given this was to occur the Scheme would continue to be afforded this standard of protection over its lifetime, accounting for the predicted impacts of climate change.

5.5.2 The main source of flood risk is therefore a residual risk associated with a breach in the River Thames defences in combination with extreme tide levels.

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6. FLOOD MITIGATION MEASURES

6.1 Northern and Southern Worksites

6.1.1 As outlined in Section 5, the northern and southern worksites are potentially at residual risk of fluvial and coastal flooding, with existing river defences significantly reducing actual flood risk to the Scheme from the tidally dominated River Thames.

6.1.2 It is understood that construction of the Scheme will not impact on existing river walls, with a minimum clearance beneath the bored tunnel alignment and the defence foundations of 4m to the south and 5m to the north, or cause any increase in existing risk from this form of flooding, therefore no fluvial/coastal flood mitigation measures are required.

6.2 The Tunnel

6.2.1 In addition to the residual flood risk from the tidal River Thames, the permeability of the flood plain alluvial layers makes ground water infiltration a possible source of flood risk to the bored tunnel. This risk will be managed by design. Ingress to the bored tunnel will be restricted through seals between segments in the primary lining. Ingress into the cut and cover tunnel sections and to the retained cut (where that lies below groundwater level) will be through construction of a ‘trough’ with waterbars between the secant piled walls and the concrete base slab.

6.2.2 Flood risk to the tunnel from surface water runoff will also be mitigated by design, with cut off drainage provided at the tunnel portals to stop ingress of runoff from the approach roads. When the capacity of this system is exceeded, surface water flows would be collected by the combined drainage and kerb unit within the tunnel, draining to the low point sump. From here drainage discharges will be pumped to the northern services building compound where an impounding foul sump would be provided under the car park. This would then ultimately discharge to sewer or to the River Thames.

6.3 Flood Gates

6.3.1 Consideration has been given to providing flood gates at the tunnel entrances’, which could be activated in the event of flooding being predicted. However, even if such gates were provided, the tunnel could not continue to operate during a flood event. The possibility of a flood resulting from a breach in the defences has therefore been weighed

against the damage that would be done to the tunnel and associated infrastructure in the case of the tunnel filling with water. Although some damage and substantial impact to key tunnel systems, for example, lighting and ventilation systems, would inevitably be incurred, requiring extensive repair and replacement, the tunnel structure itself is substantially resilient to immersion. It is therefore considered uneconomical to provide flood gates to guard against water ingress to the tunnel in the very unlikely event of the River Thames defences being breached.

6.3.2 It is recommended that the residual flood risk associated with defence breach, be managed through maintenance and improvement of the flood defences, as required, rather than by providing flood gates, which have operational implications.

6.4 Floodplain Compensation

6.4.1 As the Scheme is located within defended Flood Zone 3, there is no requirement to consider floodplain compensation.

6.5 Flood Warning and Evacuation

6.5.1 The Scheme is located immediately adjacent to the River Thames. In the event of a flood associated with a breach in the river defences, the Scheme would be subject to relatively deep and rapid inundation. A Flood Warning and Evacuation Plan has been prepared covering both the construction phase of the Scheme and its operational life time. Key to the plan is a link into the Environment Agency’s advanced flood warning service.

6.5.2 In the implementation of the flood management plan during the construction phase, on-site operatives would be able to assess the need to put evacuation and Scheme shutdown procedures into action. During the operational lifetime of the Scheme on-site operatives would be able to assess the need to put tunnel closure and evacuation procedures into action.

7. SUMMARY

7.1.1 The Scheme comprises a new road tunnel linking areas north and south of the River Thames between Silvertown and the Greenwich Peninsula. The main objective of this new tunnel would be to reduce delays and closures at the Blackwall Tunnel by improving connections and offering an alternative crossing option. It is understood that a new tunnel would also help London's economy and population continue to grow, and would help to regenerate the area.

7.1.2 Land on both sides of the River Thames is gently undulating with ground levels in the region of 5mOD to 7mOD on the north side of the river and in the region of 3mOD to 7mOD on the south side. The bed of the River Thames is anticipated to have a gentle transverse dip ranging in elevation from 0mOD to -12mOD.

7.1.3 To the north of the River Thames the Scheme is mostly located in Flood Zone 3 but there is a small area located in Flood Zone 2, in the 1 in 1000 year floodplain. These areas benefit from flood defences which reduce the actual flood risk to the Scheme.

7.1.4 To the south of the River Thames the Scheme is located wholly within Flood Zone 3 in the 1 in 200 year floodplain of the River Thames and also benefits from defences that reduce the actual flood risk to the Scheme.

7.1.5 Silvertown tunnel is classed as 'Essential Infrastructure' by the NPPF. Therefore the Scheme needs to pass the Sequential and Exception Tests.

7.1.6 It is considered that Newham Council and the Royal Borough of Greenwich can demonstrate satisfaction of the Sequential Test since it would not be possible to locate the Silvertown Tunnel elsewhere in Flood Zone 1, whilst achieving the main purposes of the Scheme to reduce congestion at the Blackwall Tunnel.

7.1.7 The main source of flooding to the Scheme is from the breach of existing river defences in combination with extreme tide levels. This risk will be better understood following bespoke Hyder breach modelling that is currently underway.

7.1.8 The Environment Agency breach model results suggest that the Scheme is defended up to a 1 in 1000 year 'present day' event. However the current defences are lower than the future 2100 predicted water levels, so

if the defences are not raised to the proposed levels set out in the TE2100 plan, there is potential for future overtopping of the defences.

7.1.9 A River Wall Structural Condition Survey (Appendix 16.D) for the lengths of river wall located within the red line boundary on both sides of the river has been conducted by Atkins. The findings show that the majority of the defences are classed as either a condition grade 3 or 4, where 1 is classed as very good and 5 is classed as very poor. The survey also concludes that all sections of river wall have the potential to support future raising.

7.1.10 Based on existing available information, it is considered that part of the northern worksite area is at higher risk of flooding from surface water, due to the poor condition of existing local drainage infrastructure. However, Scheme design will mitigate this risk and presents an opportunity to provide betterment.

7.1.11 Residual risk to the Scheme and its users would be mitigated by the operation of a flood management plan, linked into the Environment Agency's advanced flood warning service. The plan would also be relevant to the construction phase of the Scheme.

Annex A Flood Product Data

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