Revision Schedule

Southwark Surface Water Management Plan
March 2011

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<tr>
<th>Rev</th>
<th>Date</th>
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<th>Prepared by</th>
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<tr>
<td>01</td>
<td>31/03/2011</td>
<td>Draft Report</td>
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<th>DEFINITION</th>
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<tbody>
<tr>
<td>BGS</td>
<td>British Geological Survey</td>
</tr>
<tr>
<td>DEFRA</td>
<td>Department for Environment, Fisheries and Rural Affairs</td>
</tr>
<tr>
<td>EA</td>
<td>Environment Agency</td>
</tr>
<tr>
<td>RBMP</td>
<td>River Basement Management Plan</td>
</tr>
<tr>
<td>LiDAR</td>
<td>Light Detection and Ranging</td>
</tr>
<tr>
<td>SFRA</td>
<td>Strategic Flood Risk Assessment</td>
</tr>
<tr>
<td>SUDS</td>
<td>Sustainable Drainage Systems</td>
</tr>
<tr>
<td>SWMP</td>
<td>Surface Water Management Plan</td>
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## Glossary

<table>
<thead>
<tr>
<th>TERM</th>
<th>DEFINITION</th>
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<tbody>
<tr>
<td>Aquiclude</td>
<td>Formations that may be sufficiently porous to hold water, but do not allow water to move through them.</td>
</tr>
<tr>
<td>Aquifer</td>
<td>Layers of rock sufficiently porous to hold water and permeable enough to allow water to flow through them in quantities that are suitable for water supply.</td>
</tr>
<tr>
<td>Aquitard</td>
<td>Formations that permit water to move through them, but at much lower rates than through the adjoining aquifers.</td>
</tr>
<tr>
<td>Climate Change</td>
<td>Long term variations in global temperature and weather patterns, caused by natural and human actions.</td>
</tr>
<tr>
<td>Flood defence</td>
<td>Infrastructure used to protect an area against floods, such as floodwalls and embankments; they are designed to a specific standard of protection (design standard).</td>
</tr>
<tr>
<td>Floods and Water Management Act</td>
<td>Legislation constituting part of the UK Government’s response to Sir Michael Pitt’s Report on the Summer 2007 floods, the aim of which is to help protect ourselves better from flooding, to manage water more sustainably and to improve services to the public.</td>
</tr>
<tr>
<td>Fluvial flooding</td>
<td>Flooding by a river or a watercourse.</td>
</tr>
<tr>
<td>Groundwater</td>
<td>Water that is underground. For the purposes of this study, it refers to water in the saturated zone below the water table.</td>
</tr>
<tr>
<td>Pluvial Flooding</td>
<td>Flooding as a result of high intensity rainfall when water is ponding or flowing over the ground surface before it enters the underground drainage network or watercourse, or cannot enter it because the network is full to capacity.</td>
</tr>
<tr>
<td>Risk</td>
<td>The product of the probability and consequence of the occurrence of an event.</td>
</tr>
<tr>
<td>Sewer flooding</td>
<td>Flooding caused by a blockage, undercapacity or overflowing of a sewer or urban drainage system.</td>
</tr>
<tr>
<td>Sustainable Drainage Systems</td>
<td>Methods of management practices and control structures that are designed to drain surface water in a more sustainable manner than some conventional techniques. The current study refers to the ‘infiltration’ category of sustainable drainage systems e.g. soakaways, permeable paving.</td>
</tr>
</tbody>
</table>
1 Introduction

1.1 Groundwater Flooding

1.1.1 Groundwater flooding occurs as a result of water rising up from the underlying aquifer or from water flowing from springs. This tends to occur after long periods of sustained high rainfall, and the areas at most risk are often low-lying where the water table is more likely to be at shallow depth. Groundwater flooding is known to occur in areas underlain by principal aquifers, although increasingly it is also being associated with more localised floodplain sands and gravels.

1.1.2 Groundwater flooding tends to occur sporadically in both location and time, and tends to last longer than fluvial, pluvial or sewer flooding. Basements and tunnels can flood, buried services may be damaged, and storm sewers may become ineffective, exacerbating the risk of surface water flooding. Groundwater flooding can also lead to the inundation of farmland, roads, commercial, residential and amenity areas.

1.1.3 It is also important to consider the impact of groundwater level conditions on other types of flooding e.g. fluvial, pluvial and sewer. High groundwater level conditions may not lead to widespread groundwater flooding. However, they have the potential to exacerbate the risk of pluvial and fluvial flooding by reducing rainfall infiltration capacity, and to increase the risk of sewer flooding through sewer / groundwater interactions.

1.1.4 The need to improve the management of groundwater flood risk in the UK was identified through Defra’s Making Space for Water strategy. The review of the July 2007 floods undertaken by Sir Michael Pitt highlighted that at the time no organisation had responsibility for groundwater flooding. The Flood and Water Management Act identified new statutory responsibilities for managing groundwater flood risk, in addition to other sources of flooding and has a significant component which addresses groundwater flooding.

1.2 The Current Report

1.2.1 The Greater London Authority (GLA) has commissioned Capita Symonds with Scott Wilson to complete Tier 2 of the Surface Water Management Plan (SWMP) for Southwark Borough Council (BC). A SWMP is a plan which outlines the preferred surface water management strategy in a given location. In this context surface water flooding describes flooding from sewers, drains, groundwater, and run-off from land, small water courses and ditches that occurs as a result of heavy rainfall (DEFRA, March 2010).

1.2.2 The current report provides an intermediate assessment of groundwater flooding susceptibility as part of the SWMP Tier 2, and provides recommendations for Tier 3.

1.2.3 The following sections outline the geology and hydrogeology in the Southwark BC administrative area. From this analysis:

- Potential groundwater flooding mechanisms are identified;
- Evidence for groundwater flooding is discussed;
- Areas susceptible to groundwater flooding are recognised; and
- Recommendations are provided for further investigation.
2 Topography, Geology and Hydrogeology

2.1 Topography and Hydrology

2.1.1 The administrative area of Southwark BC lies in the centre of London, with its northern boundary demarked by the west to east flowing River Thames. The borough is elongated in a north to south direction, with its southern boundary 8 km south of the River Thames, a little beyond Dulwich. There are no other main watercourses within the Southwark BC; all other historic drainage catchments have been incorporated into the main Thames Water sewerage system (SFRA, Feb 2008 (Final Rev01)).

2.1.2 With respect to topography, Southwark BC is divided into two areas by the 5 maOD contour, which is approximated by the west to east orientated A202. It is considered that in the southern half of the borough, there is no risk of fluvial and/or tidal flooding (SFRA, Feb 2008 (Final Rev01)); the land is relatively undulating, rising away from the River Thames and reaching around 100 maOD near the southern tip of the borough at Crystal Palace.

2.1.3 To the north of the A202, in the area of Bermondsey and Camberwell, the borough is characterised by a ‘basin’ of low lying land. Water flows into this area following a storm event and/or failure of the River Thames defences (SFRA, Feb 2008 (Final Rev01)). Ground elevations in the centre of this basin, to the east of Walworth, are close to 0 maOD. However, they rise to around 4 to 5 maOD adjacent to the River Thames.

2.2 Geology

2.2.1 Figures 1 and 2 provide bedrock and superficial geological information for Southwark BC and the surrounding area. The geological sheet 270 (South London) presents a geological cross section, which has been used to improve the conceptual understanding of the area.

Bedrock Geology

2.2.2 The bedrock geology of the area comprises the Chalk Formation, which in turn is overlain by the Thanet Sand Formation (fine grained sand), Lambeth Group (clay with beds of sand), London Clay Formation (clay and silt) and the Claygate Member (sand, fine grained silt and clay).

2.2.3 Figure 1 shows that the London Clay Formation dominates the surface bedrock geology in much of the southern and north western parts of the Southwark BC area. However, in the Bermondsey / Deptford area to the east, an anticline in the Chalk and Palaeogene strata has exposed the Lambeth Group, Thanet Sand Formation and Chalk Formation. These units outcrop beneath the superficial deposits in much of the central (Camberwell) and north eastern parts (Bermondsey) of the Southwark BC area.

2.2.4 In the south eastern area of Southwark BC, near Dulwich and Crystal Palace, the Claygate Member overlies the London Clay Formation on higher ground. The unit is the youngest part of the London Clay Formation and comprises orange sands interbedded with pale clays. The thickness of the Claygate Member in the south east is not known, although this could be established through analysis of BGS geological logs.
Southwark Surface Water Management plan

2.2.5 The BGS sheet 270 indicates that to the north west of the Bermondsey area, the London Clay Formation is fairly thin at around 10 m thick. Where the London Clay Formation is present, the underlying Lambeth Group, Thanet Sand Formation and the Chalk are around 15 m, 7 m and 210 m thick, respectively.

2.2.6 Faulting of the bedrock geology is shown on Figure 1. The Streatham Fault at Brockwell Park in the south west and the un-named faults near Walworth further to the north have a limited influence on the outcrop geology. The Streatham Fault near Brockwell Park has a maximum recorded throw of 15 m (Geology of London, 2004), which is sufficient to cause the Lambeth Group to outcrop in this area.

Superficial Geology

2.2.7 The superficial geology of the area consists of various River Terrace Deposits, Alluvium, Peat, Head, Langley Silt Member, Interglacial Lacustrine Deposits and Sand and Gravel of Uncertain Age (Figure 2). These blanket much of the northern half of the study area where ground levels are less than around 10 maOD, but are largely absent in the southern half at higher elevations.

2.2.8 The River Terrace Deposits (gravel, sandy and clayey in part) are differentiated on the basis of altitude but are often geologically similar. The members within the study area are the Boyne Hill Gravel Member, Taplow Gravel Formation and the Kempton Park Gravel Formation.

2.2.9 The Kempton Park Gravel Formation constitutes the majority of the River Terrace Deposits in the Southwark BC area, varying between 10 to 15 m in thickness (Geology of London, 2004). The Taplow Gravel Member encroaches onto a small area near the western boundary of Southwark BC, whilst at higher elevations to the south (to the north of Herne Hill) there is a small deposit of Boyne Hill Gravel Member.

2.2.10 Alluvium deposits, consisting mainly of sand, silt and clay, broadly mark the path of the River Thames in the north of the borough. They also outcrop within a topographic depression at Newington, where there is a small deposit of Peat overlying the Alluvium.

2.2.11 In the Camberwell area there has been significant deposition of Interglacial Lacustrine deposits (organic rich mud and sand) and Langley Silt Member (sandy clay and silt), the latter formerly known as ‘Brickearth’.

2.2.12 Minor deposits of Head (clay silt, sand and gravel) are distributed in the southern half of the Southwark BC at Rye Park, Dulwich College and near to Crystal Palace. Not far from the Head deposits at Crystal Palace, the small deposit of Sand and Gravel of Uncertain Age extends along the Southwark BC boundary towards Dulwich.

2.3 Hydrogeology

2.3.1 The hydrogeological significance of the various geological units within the study area is provided in Table 1. The range of permeability likely to be encountered for each geological unit is also incorporated in Table 1, based on BGS permeability data.
Table 1 Geological Units in the Study Area and their Hydrogeological Significance

<table>
<thead>
<tr>
<th>Geological Unit</th>
<th>Permeability</th>
<th>Hydrogeological Significance</th>
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<tbody>
<tr>
<td>Head</td>
<td>Very low to very high</td>
<td>Secondary Undifferentiated. Variable (probably an aquitard but sand or gravel horizons may locally form an aquifer).</td>
</tr>
<tr>
<td>River Terrace Deposits (Boyn Hill Gravel Member, Kempton Park Gravel Formation, and Taplow Gravel Formation)</td>
<td>High to very high</td>
<td>Secondary Aquifer (A)</td>
</tr>
<tr>
<td>Superficial Deposits</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alluvium along River Thames</td>
<td>Not defined / not permeable</td>
<td>Secondary Undifferentiated</td>
</tr>
<tr>
<td>Sand and Gravel of Uncertain Age</td>
<td>High to very high</td>
<td>Secondary Aquifer (A)</td>
</tr>
<tr>
<td>Interglacial Lacustrine Deposits</td>
<td>Not defined / not permeable</td>
<td>Unproductive strata</td>
</tr>
<tr>
<td>Peat</td>
<td>Very low to low</td>
<td>Unproductive strata / Aquiclude</td>
</tr>
<tr>
<td>Langley Silt Member (Brickearth)</td>
<td>Not defined / not permeable</td>
<td>Unproductive strata</td>
</tr>
<tr>
<td>Bedrock Geology</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chalk Formation</td>
<td>Very high</td>
<td>Principal Aquifer</td>
</tr>
<tr>
<td>Thanet Sand Formation</td>
<td>High</td>
<td>Secondary Aquifer (A)</td>
</tr>
<tr>
<td>Lambeth Group</td>
<td>Very low to moderate</td>
<td>Secondary Aquifer (A)</td>
</tr>
<tr>
<td>Harwich Formation</td>
<td>High to very high</td>
<td>Secondary Aquifer (A)</td>
</tr>
<tr>
<td>London Clay Formation</td>
<td>Very low to low</td>
<td>Aquiclude</td>
</tr>
<tr>
<td>Claygate Member</td>
<td>Low to high</td>
<td>Secondary Aquifer (A)</td>
</tr>
</tbody>
</table>

‘Principal Aquifer’ - layers that have high permeability. They may support water supply and/or river base flow on a strategic scale.
‘Secondary Aquifer (A)’ - 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.
‘Secondary Undifferentiated’ - In most cases, the layer in question has previously been designated as both minor and non-aquifer in different locations due to the variable characteristics of the rock type.
‘Aquitard’ - allows some groundwater movement (see glossary)
‘Aquitlude’ - does not allow groundwater movement (see glossary)

Bedrock Hydrogeology

2.3.2 The London Clay Formation is an aquiclude and does not permit significant groundwater flow. It is classified by the Environment Agency as unproductive strata.

2.3.3 The physical properties for minor aquifers in England and Wales (Allen et al., 1997) suggests ‘The Thanet Sand Formation, Lambeth Group and the Harwich Formation are often considered as a single groundwater unit, known as the ‘Basal Sands’ aquifer, which is in hydraulic continuity with the Chalk’.

2.3.4 In the southern half and north west of the Southwark BC, the Chalk and Basal Sands aquifer is overlain by London Clay Formation, which does not permit groundwater flow and confines the water table in the Chalk and Basal Sands aquifer. In these areas the Chalk and overlying Basal Sands are not considered pertinent to the study. However, the Chalk, Thanet Sand Formation and Lambeth Group do outcrop in the Camberwell, Bermondsey and Deptford area and in this region they are of interest to this study.
2.3.5 The Claygate Member permits groundwater flow but can significantly vary in permeability. The Claygate Member is hydraulically separated from that of the Chalk and Basal Sands by the significant thickness of London Clay Formation. This scenario may lead to the development of a perched water table(s), which may also be in hydraulic continuity with overlying superficial deposits. The Claygate Member only has a small outcrop area in Southwark BC, near Dulwich and Crystal Palace in the south, and is therefore of limited interest to the current study.

Superficial Hydrogeology

2.3.6 River Terrace Deposits within the study area are expected to behave as a Secondary Aquifer (A) and are of significant interest to this study. The River Terrace Deposits are likely to form perched aquifers in the north of the Southwark BC area where they overlie the London Clay Formation bedrock aquiclude.

2.3.7 The Sands and Gravels of Uncertain age may also form perched aquifers in the south of the borough and could be in hydraulic continuity with the underlying Claygate Member. However, they have a very small outcrop area in Southwark BC and are therefore of limited interest to this study.

2.3.8 Head deposits are generally expected to behave as aquitards, although sand and gravel horizons may locally form a secondary aquifer depending on their lateral extent and thickness. These deposits may be in hydraulic continuity with the bedrock geology aquifers in the south west (Brockwell Park area) of the Southwark BC, where the Lambeth Group outcrops beneath the superficial deposits.

2.3.9 Alluvium along the River Thames is classified as Secondary Undifferentiated by the Environment Agency, owing to the inconsistent permeability caused by variable clay content. The BGS permeability data set does not consider the Alluvium along the River Thames, which suggests limited data. The possible presence of interbedded Peat would further reduce the hydraulic conductivity (permeability), as the Peat is expected to behave as an aquitard.

2.3.10 The Langley Silt Member and Interglacial Lacustrine deposits, like the Peat, are not regarded by the Environment Agency or the BGS to be permeable and are therefore of little interest to the study.

Groundwater Levels

Bedrock Geology

2.3.11 Water level monitoring data was provided by the Environment Agency for seven Chalk observation boreholes in the study area and the associated hydrographs are provided in Appendix 1; borehole locations are shown on Figures 1 and 2.

2.3.12 During the period 1987-2010, Chalk water levels were observed to be closest to ground level at the Earl PS (TQ37/268) and Yalding Road (TQ37/7E) observation boreholes, located near the Chalk outcrop in the Bermondsey area. During this period, water levels at Earl PS and Yalding Road ranged between 1.7 to 6.6 m and 5.5 to 8.1 m below ground level, respectively; the highest water levels were observed in 1994. The available LIDAR data shows that the Earl PS borehole is located in a topographic low (0.1 to 1 maOD), indicating a near worst case scenario for depth to groundwater; Southwark Park has a ground elevation of around 0 maOD, and therefore groundwater levels may be closer to ground surface at this location.
2.3.13 Chalk water levels to the west of the Chalk outcrop are represented by the Sunshine Services observation borehole (TQ37/120). The monitored water levels demonstrate a slow but steady rise in groundwater level between 1987 and 1999. However, in the year 2000, there was a sharp fall in Chalk water levels at Sunshine Services (TQ37/120). This is likely to be in response to increased groundwater abstractions in the Battersea and Brixton areas (Source Protection Zones are shown on Figure 4). Following a brief recovery in 2002, groundwater levels continued to fall until around 2005. Since 2005, water levels have fluctuated between 15 - 20 m below ground level.

2.3.14 Chalk water levels to the north of the Chalk outcrop are represented by the record for Rotherhithe observation borehole (TQ37/276). The hydrograph for the borehole shows that during the period 1994 to 2000 the water level fluctuated between 13.5 and 22.5 metres below ground level, in presumed response to groundwater abstractions. However, since the year 2000, Chalk water levels in this area have remained around 20 metres below ground level.

2.3.15 Groundwater levels in the East Dulwich and Honour Oak area of Southwark BC were around 25 to 40 m below ground level during the period 1986 to 1997, as shown by the records for Honour Oak PS (TQ37/32) and Dulwich Hospital (TQ37/157) in Appendix 1. Following 1997, groundwater abstractions close to Honour Oak PS (Source Protection Zones are shown on Figure 4) resulted in a lowering of groundwater levels in this region. In 2009 / 2010 groundwater levels at Honour Oak PS and Dulwich Hospital were around 40 to 45 m and 30 to 35 m below ground level, respectively.

2.3.16 Chalk water levels in the south of the Southwark BC area are represented by the record for Rock Hill observation borehole (TQ37/267A). The hydrograph shows that Chalk water levels fluctuate between 103 and 113 m below ground level; they are deeper than in the north of Southwark BC, as ground elevation is higher.

2.3.17 The Environment Agency does not monitor groundwater levels in the Thanet Sand Formation, Lambeth Group or Claygate Member in the Southwark BC area.

**Superficial Geology**

2.3.18 Deposits of Alluvium, Head, and in particular, River Terrace Deposits, are expected to form perched aquifers over the London Clay Formation aquiclude in the lower elevation areas i.e. the northern half of Southwark BC. The Environment Agency does not monitor groundwater levels in any of these superficial aquifers. It is recommended that under Tier 3 of the Drain London project, borehole logs are obtained from the BGS, which often provide details of water strikes and therefore an indication of depth to groundwater.

**Hydraulic Relationships**

2.3.19 **Bedrock / Superficial Deposit Groundwater Interactions**

2.3.20 The London Clay Formation aquiclude overlies the Chalk, Thanet Sand Formation and Lambeth Group aquifers in large areas of southern and north west Southwark BC, which hydraulically separates them from overlying permeable superficial deposits (namely the River Terrace Deposits). In these areas superficial deposit / bedrock groundwater interactions will not exist.

2.3.21 The Chalk Formation, Thanet Sand Formation and Lambeth Group are expected to be in some hydraulic continuity, although the Environment Agency and Southwark BC only monitor Chalk
groundwater levels i.e. there is currently no evidence for this. These Formations, particularly the Lambeth Group, outcrop in large areas of the north east, central and south western parts of the Southwark BC (Figure 1). However, the available monitoring data indicate that Chalk groundwater levels are only close to ground level in the north east area of Southwark BC, near Southwark Park. Therefore, the potential for superficial deposit / bedrock groundwater interactions mainly exist in this area.

2.3.22 At the southern tip of the Southwark BC area, the London Clay Formation is overlain by a small outcrop of the Claygate Member, which can be permeable. In this region the small overlying superficial deposits of Sand and Gravel of Uncertain age may be in continuity with the Claygate Member and springs may emerge from permeable horizons and the London Clay Formation / Claygate Member interface.

**Surface Water / Groundwater Interactions**

2.3.23 With the exception of the River Thames, there are no other main watercourses within the borough; all other historic drainage catchments have been incorporated into the main Thames Water sewerage system. Therefore, perched groundwater / surface water interactions are likely to be restricted to lower elevation areas close to the River Thames, providing the Alluvium deposits are permeable. However, these interactions will be significantly reduced by flood defence works along the River Thames. An improved understanding of flood risk could be gained by undertaking monitoring of groundwater levels / river stage.

**Water Supply Abstractions**

2.3.24 In the 19th Century groundwater water supplies in London were obtained from the shallow superficial and bedrock deposits. In the early 20th Century this was abandoned in favour of deeper boreholes and wells into the Chalk (Jones *et al.*, 2000).

2.3.25 Environment Agency water level data indicate that Chalk water levels are suppressed in some areas of the Southwark BC due to groundwater abstractions; it is likely that these are for public water supply. These abstractions are of interest to this study, as they have the potential to influence future groundwater flooding susceptibility.

2.3.26 There may be some smaller private abstractions from the superficial deposits and this information is held by the Environment Agency.

**Artificial Groundwater Recharge**

2.3.27 Water mains leakage data for the Southwark BC administrative area were not provided for this study. It should be noted that additional recharge to perched groundwater tables by leaking mains could result in a local rise in groundwater levels. This rise might not prove significant under dry conditions, but could exacerbate the risk from groundwater flooding and other sources of flooding following periods of heavy rainfall.

2.3.28 The drainage/sewer network can act as a further source of artificial recharge. When pipes are installed within principal or secondary aquifers, the groundwater and drainage network may be in partial hydraulic connection. When pipes are empty, groundwater may leak into the drainage network with water flowing in through cracks and porous walls, draining the aquifer and reducing groundwater levels. During periods of heavy rainfall when pipes are full, leaking pipes can act as recharge points, artificially recharging the groundwater table and subsequently increasing groundwater levels with potential impacts on groundwater quality.
3 Assessment of Groundwater Flooding Susceptibility

3.1 Groundwater Flooding Mechanisms

3.1.1 Based on the hydrogeological conceptual understanding of the study area, the potential groundwater flooding mechanisms that may exist are:

- **Claygate Member (bedrock) outcrop in Dulwich / Crystal Palace area:** Water levels within the outcropping Claygate Member will be perched on top of the London Clay Formation aquiclude. This means that basements / cellars in this area may be at risk from groundwater flooding following periods of prolonged rainfall, increased utilisation of infiltration SUDs and / or artificial recharge from leaking pipes.

- **Chalk Formation, Thanet Sand Formation and Lambeth Group outcrop where overlying superficial deposits are permeable and ground elevations are low (e.g. Southwark Park area):** Groundwater flooding is often associated with Chalk catchments, which allow groundwater levels to rise to the near surface through permeable subsoil following long periods of wet weather and / or reductions in historic abstractions. Therefore, basements / cellars in this area may be at risk from groundwater flooding following periods of prolonged rainfall, decreased abstraction, increased utilisation of infiltration SUDs and / or artificial recharge from leaking pipes.

- **Superficial aquifers along the River Thames:** groundwater flooding may be associated with the substantial sand and gravel River Terrace Deposits, or to a lesser degree with Head and Alluvium deposits, where they are in hydraulic continuity with surface water courses. River levels may rise following high rainfall events but still remain ‘in-bank’, and this can trigger a rise in groundwater levels in the associated superficial deposits. The properties at risk from this type of groundwater flooding are probably limited to those with basements / cellars, which have been constructed within the superficial deposits. It is noted that groundwater / surface water interactions will be limited by defence works to the River Thames. However, without evidence in the form of groundwater levels, this groundwater flooding mechanism cannot be ruled out.

- **Superficial aquifers not in hydraulic continuity with surface water courses (various locations):** a third mechanism for groundwater flooding is associated with substantial River Terrace Deposits (gravel and sand), Head deposits and Sand and Gravel of Uncertain age, but occurs where they are not hydraulically connected to surface water courses. Perched groundwater tables can exist within these deposits, developed through a combination of natural rainfall recharge and artificial recharge e.g. leaking water mains. The properties at risk from this type of groundwater flooding are probably limited to those with basements / cellars. It is also worth noting that groundwater levels are likely to be closer to ground level in those areas where historic / lost rivers were located i.e. where ground elevation is lower.

- **Impermeable (silt and clay) areas downslope of superficial aquifers:** a fourth mechanism for groundwater flooding may occur where groundwater springs / seepages form minor flows and ponding over impermeable strata where there is poor drainage. This mechanism may occur as a result of natural (e.g. rainfall) or artificial (e.g. water main leakage) recharge.
- **Artificial ground in various locations**: a final mechanism for groundwater flooding may occur where the ground has been artificially modified to a significant degree. If this artificial ground is of substantial thickness and permeability, then a shallow perched water table may exist. This could potentially result in groundwater flooding at properties with basements, or may equally be considered a drainage issue. Areas mapped by the BGS as containing artificial ground are shown in Figures 1, 2 and 3. Artificial ground deposits over the London Clay Formation in the south, or Alluvium in the Rotherhithe area, may allow for the development of a perched aquifer depending on the composition of the artificial ground.

### 3.2 Evidence of Groundwater Flooding

#### 3.2.1 Figures 1 and 2 show the location of a number of groundwater flooding incidents between 2000 and 2010 within the study area that have been reported to the Environment Agency. In addition, 15 potential groundwater flooding incidents provided by Southwark BC are also shown. Table 2 provides details for the reported groundwater incidents, including the local geology and the date of the incident.

**Table 2 Groundwater Flooding Records**

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<thead>
<tr>
<th>Bedrock Geological Unit*</th>
<th>Overlying Superficial Deposits*</th>
<th>Grid Reference</th>
<th>N**</th>
<th>Reported Incident</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alluvium</td>
<td>RTD – Kempton Park Gravel Formation</td>
<td>TQ3234480451</td>
<td>1</td>
<td>Water in lower basement</td>
<td>10/02/2009</td>
</tr>
<tr>
<td>None</td>
<td>RTD – Boyin Hill Gravel Member</td>
<td>TQ3234480451</td>
<td>3</td>
<td>Flooding in Basement</td>
<td>06/04/2001</td>
</tr>
<tr>
<td>None</td>
<td></td>
<td>TQ3234480451</td>
<td>6</td>
<td>spring in basement</td>
<td>04/04/2002</td>
</tr>
<tr>
<td>None</td>
<td>None but nr RTD - Boyin Hill Gravel Member</td>
<td>TQ3234480451</td>
<td>7</td>
<td>Water appeared in cellar, fluctuates daily, rises after rain</td>
<td>20/08/2002</td>
</tr>
<tr>
<td>None</td>
<td>None but nr RTD - Boyin Hill Gravel Member</td>
<td>TQ3234480451</td>
<td>8</td>
<td>Waterlogging</td>
<td>08/11/2000</td>
</tr>
<tr>
<td>None</td>
<td>None but on artificial land</td>
<td>TQ3234480451</td>
<td>10</td>
<td>Water in basement for three months since September 2009.</td>
<td>03/12/2009</td>
</tr>
<tr>
<td>Alluvium</td>
<td>None but nr RTD - Boyin Hill Gravel Member</td>
<td>TQ3234480451</td>
<td>11</td>
<td>Flooded. Groundwater related?</td>
<td>25/05/2006</td>
</tr>
<tr>
<td>Alluvium</td>
<td>None but nr RTD - Boyin Hill Gravel Member</td>
<td>TQ3234480451</td>
<td>12</td>
<td>Waterlogged Garden</td>
<td>18/04/2001</td>
</tr>
<tr>
<td>London Clay Formation</td>
<td>None but nr artificial land</td>
<td>TQ3234480451</td>
<td>13</td>
<td>Water in basement</td>
<td>05/04/2001</td>
</tr>
<tr>
<td>RTD – Kempton Park Gravel Formation</td>
<td>TQ3234480451</td>
<td>14</td>
<td>Water seeping into basement flat</td>
<td>07/01/2002</td>
<td></td>
</tr>
<tr>
<td>RTD – Kenton Park Gravel Formation</td>
<td>-</td>
<td>15</td>
<td>Dampness causing power to trip</td>
<td>12/6/2006</td>
<td></td>
</tr>
<tr>
<td>RTD – Kenton Park Gravel Formation</td>
<td>-</td>
<td>18</td>
<td>Basement flooding due to blocked drain in road</td>
<td>2/10/2006</td>
<td></td>
</tr>
<tr>
<td>RTD – Kenton Park Gravel Formation / Langley Silt Member</td>
<td>-</td>
<td>21</td>
<td>Blocked gully resulting in localised ponding</td>
<td>20/11/2006</td>
<td></td>
</tr>
<tr>
<td>RTD – Interglacial Lacustrine Deposits / Langley Silt Member</td>
<td>-</td>
<td>23</td>
<td>Blocked gully resulting in localised ponding</td>
<td>7/12/2006 &amp; 19/2/2007</td>
<td></td>
</tr>
<tr>
<td>RTD – Kenton Park Gravel Formation</td>
<td>-</td>
<td>29</td>
<td>Subway Flooded</td>
<td>29/1/2007</td>
<td></td>
</tr>
</tbody>
</table>
Table 2 demonstrates that many of the flooding incidents are referenced as flooding of basements, which is a common outcome of a rising water table following a period of heavy or consistent rainfall, particularly in shallow aquifers often associated with superficial deposits.

Incidents 3, 6, 14, 15, 17, 18, 20, 22, 23, 24, 26, 28 and 29 are reported to be on the London Clay Formation where it is overlain by River Terrace Deposits. A water table is expected to be present within these superficial deposits, perched above the London Clay Formation aquiclude. These incidents are therefore likely to be true groundwater flooding incidents.

Numbers 7 to 10 and 13 are located over the London Clay Formation where there are no overlying superficial deposits. The London Clay Formation is an aquiclude and does not permit groundwater flow. Therefore based on the available information to date, these incidents are probably related to poor drainage over clayey soils following heavy rainfall i.e. they are not true groundwater flooding incidents. However, it is worth noting that a number of these incidents may be located downslope of superficial deposit aquifers or permeable artificial land, and springs / seepages may form part of the flood waters. Rolling ball analysis would be required to confirm this as part of a more detailed study.

Incident numbers 5, 19 and 21 are located over the Lambeth Group, which is overlain by the Kempton Park Gravel Formation aquifer or Interglacial Lacustrine Deposits. As identified in Section 2, Chalk water levels were at least 15 m below ground level at the dates of the reported incidents. This suggests that these groundwater flooding incidents are either related to (i) a perched aquifer within the Kempton Park Gravels / Interglacial Lacustrine Deposits (ii) a perched aquifer within the Lambeth Group where a basement penetrates through the superficial deposits, or (iii) they are not true groundwater flooding incidents.

Incident number 4 is located on Alluvium deposits that overlie the Chalk outcrop. Due to the incident indicating flooding of a garage and not a basement, it is likely that it is a result of poor drainage i.e. not related to groundwater flooding. This is because water levels within the underlying Chalk aquifer are below ground level and the overlying Alluvium is understood to have low permeability characteristics that will impede infiltration of water.

Incidents 1 and 2 are reported to be on the London Clay Formation / Lambeth Group but are located over Alluvium deposits adjacent to the River Thames. Whilst Alluvium is generally considered to have low permeability characteristics, without more local information such as the thickness and composition of the Alluvium deposits, and the hydraulic continuity with the River Thames, these two incidents cannot be disregarded as groundwater flooding incidents.
3.2.8 Incidents 16 and 27 are located on the Thanet Sand Formation aquifer, which is overlain by Langley Silt Member superficial deposits. As identified in Section 2, Chalk water levels, which are expected to be in some hydraulic continuity with the Thanet Sand Formation, are expected to be a number of metres below ground level in this area. The incidents do not refer to basement flooding, and so it is likely that these incidents are related to poor drainage i.e. they are not true groundwater flooding incidents. The Langley Silt Member is believed to have low permeability characteristics that will impede infiltration of water.

3.3 Groundwater Flooding Susceptibility Datasets

Increased Potential for Elevated Groundwater

3.3.1 Areas where there is increased potential for groundwater levels to rise within 2 m of ground surface, following periods of higher than average recharge, are shown in Figure 3. These are separated into permeable superficial deposits and bedrock (consolidated) aquifers. The data set was produced for the whole of the Drain London project area, derived from four individual data sources:

- British Geological Survey (BGS). Groundwater Flood Susceptibility maps;
- Environment Agency (EA). Thames Estuary, 2100 groundwater hazard maps;
- Jacobs. Groundwater emergence maps; and
- JBA. Groundwater flood maps.

3.3.2 Owing to the presence of the London Clay Formation aquiclude across much of the Southwark BC area and suppressed bedrock groundwater levels, the main groundwater flooding mechanisms are associated with perched groundwater tables within permeable superficial deposits.

3.3.3 Figure 3 shows that within the Southwark BC area, the increased potential for elevated groundwater is associated with permeable superficial deposits, and to a lesser degree bedrock (consolidated) aquifers where the Thanet Sand Formation outcrops and the Langley Silt Member is absent. This is in broad agreement with the groundwater flooding mechanisms identified in Section 3.1. The permeable superficial deposits that have been identified as having an increased potential for elevated groundwater are the River Terrace Deposits and Head. In addition, some areas of artificial ground such as those in Rotherhithe or Honor Oak are also identified as having an increased potential for elevated groundwater.

3.3.4 In general, the areas identified by the data as having an increased potential for elevated groundwater are sensible. There is a good correlation with reported groundwater flooding incidents in the northern half of the Southwark BC. Although there is a poor correlation in the southern half of the borough, as identified in Section 3.2, it is possible that many of the groundwater incidents in the southern area are misreported i.e. they are not related to groundwater conditions.
3.4 Summary of Groundwater Flooding Susceptibility

Current Susceptibility

Locations where Lambeth Group / Thanet Sand Formation (Basal Sands) are overlain by permeable River Terrace Deposits in the Bermondsey and Camberwell area

3.4.1 The Lambeth Group and Thanet Sand Formation are both secondary aquifers and are water bearing. The mapping (Figure 3) suggests that there is increased potential for elevated groundwater levels in the Camberwell area where these aquifers are overlain by the permeable Kempton Park Gravel Formation deposits.

3.4.2 In addition, the Environment Agency water level data for the Chalk aquifer suggests that there is increased potential for elevated groundwater in the Bermondsey area near Southwark Park. Groundwater levels in the Lambeth Group and Thanet Sand Formation will be, in part, dependent on the degree of hydraulic continuity with the Chalk aquifer and the presence of clay horizons. Site specific investigations should therefore be carried out to confirm the depth to groundwater and monitor seasonal fluctuations before development takes place.

Locations where the Chalk Formation is overlain by Alluvium in the Bermondsey and Camberwell area

3.4.3 The Upper Chalk is a principal aquifer and is therefore water bearing. The aquifer outcrops beneath the superficial deposits in a small area between Bermondsey and Camberwell. However, the outcrop is mostly confined by Alluvium superficial deposits, which are understood to act as an aquitard. Therefore, Figure 3 largely indicates that there is a reduced potential for elevated groundwater levels. Nonetheless, site specific investigations should be carried out to confirm the depth to groundwater and the thickness and permeability of the overlying superficial deposits before development takes place. Deeper structures, such as basements, may still be vulnerable to groundwater flooding, as Chalk groundwater levels are possibly only a few metres of ground level.

Locations where London Clay Formation outcrops at surface in the southern half of Southwark BC

3.4.4 The London Clay Formation is an aquiclude and does not permit groundwater flow. Therefore in areas where there are no overlying superficial deposits and the London Clay Formation is of an appreciable thickness, the potential for elevated groundwater levels is considered to be negligible. However, where the London Clay Formation has been removed and replaced with more permeable artificial ground, there may be increased potential of elevated groundwater as groundwater becomes trapped in these deposits.

3.4.5 Finally, it is possible that groundwater springs could emerge from permeable superficial deposits and flow over the London Clay Formation, contributing to flood waters. However, surface water flooding is likely to be the main source of flooding in these areas.

Locations where London Clay Formation is overlain by River Terrace Deposits in the north west of Southwark BC

3.4.6 Figure 3 shows that the River Terrace Deposits in this area have an increased potential for elevated groundwater. Whilst no groundwater level data are available for the superficial deposits, where groundwater tables exist they are expected to be close to or at ground level.
Therefore basements and cellars may be at risk from groundwater flooding and use of structures such as sheet piling may exacerbate the problem if they intercept the water table.

Superficial deposits are likely to be variable in composition across the Southwark BC area. Site investigation will be key for any proposed development sites, to understand the local groundwater conditions, particularly those areas located near to lost rivers (where topographic lows exist).

**Locations where Claygate Member is underlain by London Clay Formation (Crystal Palace area)**

3.4.7 The Claygate Member is classified as a secondary aquifer and is water bearing, with potential for a perched groundwater table(s) on the London Clay Formation aquiclude. Consequently, site specific investigations will be important for any proposed development sites, particularly those considering basements / underground structures such as soakaways.

### 3.5 Future Potential for Elevated Groundwater

3.5.1 Susceptibility to groundwater flooding in the Southwark BC area may change as a result of climate change, changes to water management or groundwater abstraction. Further data collection and development / use of a numerical groundwater model would be useful in estimating the relative importance of these factors as part of a more detailed study.

3.5.2 One of the climate change predictions includes an increase of high rainfall events. This could lead to further groundwater flooding in the Southwark BC area due to increased perched groundwater levels and associated spring flows. It is also noted that a shift in drainage policy, with increased infiltration SUDS, may also lead to increased incidents of groundwater flooding. The small perched superficial deposit aquifers will be sensitive to increased recharge due to their limited storage capacity.

### 3.6 Importance of Long Term Groundwater Level Monitoring

3.6.1 Groundwater flow direction, depth to groundwater, topography and the degree of artificial influence in the subsurface (e.g. leaking water mains or groundwater abstractions) play an important role when considering the susceptibility of an area to groundwater flooding. Without long term (and continuous) groundwater monitoring, it is not possible to derive groundwater level contours, understand groundwater / surface water interactions or likely maximum seasonal fluctuations. Therefore it is not possible to provide a detailed assessment of increased potential for elevated groundwater or provide detailed advice on suitability for infiltration SUDS.

3.6.2 It is probably not sufficient to rely on the work undertaken by developers through the planning application process, unless longer term (and continuous) monitoring is included as a condition attached to planning approval. Groundwater levels are often only measured once, or, at most, for a number of weeks. It would be advisable for Southwark BC, in combination with the Environment Agency, to begin long term monitoring of superficial deposit and Basal Sand aquifer groundwater levels.

3.6.3 It is also important to understand how changing policies relating to infiltration SUDS can impact upon groundwater levels. For example, the introduction of infiltration SUDS (e.g. soakaways)
may cause a rise in peak groundwater levels. This could prevent soakaways from operating and the reduction in unsaturated zone thickness may not be acceptable to the Environment Agency owing to its responsibilities under the Water Framework Directive. It may also cause groundwater flooding of infrastructure, basements / cellars etc that were designed and constructed during a period of reduced groundwater recharge.

3.6.4 Long term groundwater level monitoring is required to support decision making with respect to future land development and future co-ordinated investments to reduce the risk of flooding and inform the assessment of suitability for infiltration SUDS.

Schematic demonstrating the importance of long term groundwater level monitoring
4 Water Framework Directive and Infiltration SUDS

4.1.1 The Water Framework Directive approach to implementing its various environmental objectives is based on River Basin Management Plans (RBMP). These documents were published by the Environment Agency in December 2009 and they outline measures that are required by all sectors impacting the water environment. The Thames River Basin District is considered within the current study, since infiltration Sustainable Drainage Systems (SUDS) have the potential to impact the water quality and water quantity status of aquifers.

4.1.2 Improper use of infiltration SUDS could lead to contamination of the superficial deposit or bedrock aquifers, leading to deterioration in aquifer quality status or groundwater flooding / drainage issues. However, correct use of infiltration SUDS is likely to help improve aquifer quality status and reduce overall flood risk.

4.1.3 Environment Agency guidance on infiltration SUDS is available on their website at: http://www.environment-agency.gov.uk/business/sectors/36998.aspx. This should be considered by developers and their contractors, and by Southwark BC when approving or rejecting planning applications.

Key Water Level Considerations (Figure 3)

4.1.4 The areas that may be suitable for infiltration SUDS exist where there is a combination of high ground and permeable geology. However, consideration should be given to the impact of increased infiltration SUDS on properties further down gradient. An increase in infiltration / groundwater recharge will lead to an increase in groundwater levels, thereby increasing the susceptibility to groundwater flooding at a down gradient location. This type of analysis is beyond the scope of the current report.

4.1.5 It is important to be aware of groundwater level conditions at a potential development site. The maximum likely groundwater levels should be assessed, to confirm that soakaways will continue to function even during prolonged wet conditions. The areas where there is increased potential for elevated groundwater are shown on Figure 3.

Key Geological Considerations (Figure 4)

4.1.6 The infiltration SUDS suitability assessment shown on Figure 4 is based on minimum permeability data obtained from the BGS. There also exist maximum permeability data, however, only the minimum permeability is used, as this is understood to be more representative of the bulk permeability.

4.1.7 Three permeability zones have been identified:

1) **Infiltration SUDS potentially suitable:** Minimum permeability is high or very high for bedrock (and superficial deposits if they exist).

2) **Infiltration SUDS potentially unsuitable:** Minimum permeability is low or very low for bedrock (and superficial deposits if they exist).

3) **Infiltration SUDS suitability uncertain:** Minimum permeability is low or very low for bedrock and high or very high for superficial deposits OR minimum permeability is low or very low for superficial deposits and high or very high for bedrock.
4.1.8 The third category is required because the thickness of superficial deposits is uncertain. If they are thick and impermeable, shallow soakaways may not intercept underlying higher permeability bedrock. If they are thin and permeable, but perched over impermeable bedrock, they may not have the capacity to receive the additional recharge from infiltration SUDS. Under the third category, it is particularly important that the developer undertakes an appropriate site investigation to determine infiltration SUDS suitability.

4.1.9 Figure 4 shows that there are areas between Bermondsey and Camberwell, which are potentially suitable for infiltration SUDS; these are where the Chalk Formation and Thanet Sand Formation are overlain by permeable River Terrace Deposits. The majority of the southern half of Southwark BC, and certain areas within the northern half, are potentially unsuitable for infiltration SUDS. This is owing to the outcrop of London Clay Formation, Lambeth Group or overlying impermeable superficial deposits.

4.1.10 Those areas where River Terrace Deposits exist are shown as having an uncertain suitability for infiltration SUDS. They require enhanced site investigation, as the ability of these deposits to store and transmit groundwater without causing flooding / drainage issues is uncertain.

4.1.11 It is noted that this is a high level assessment and only forms an approximate guide to infiltration SUDS suitability; a site investigation is required to confirm local conditions in all cases.

Key Water Quality Considerations (Figure 4)

4.1.12 Where possible, infiltration SUDS should be located away from areas of historic landfill (as shown on Figure 4) and areas of known contamination or risk of contamination. This is to ensure that the drainage does not re-mobilise latent contamination or exacerbate the risk to groundwater quality and possible down gradient groundwater receptors, such as abstractors, springs and rivers. A preliminary groundwater risk assessment should be included with the planning application.

4.1.13 Restrictions on the use of infiltration SUDS also apply to those areas within Source Protection Zones (SPZ). Developers must ensure that their proposed drainage designs comply with the available Environment Agency guidance.
5 Conclusions and Recommendations

5.1 Conclusions

5.1.1 The following conclusions can be drawn from the current study:

- The London Clay Formation hydraulically separates the underlying Chalk principal aquifer and Basal Sands (Thanet Sand Formation and Lambeth Group) secondary aquifers from the overlying superficial deposits in the majority of the southern half and north west area of Southwark BC. However, in the Camberwell and Bermondsey area the London Clay Formation is absent and hydraulic continuity between bedrock and superficial deposit aquifers may exist. Whilst there is good monitoring of Chalk groundwater levels in the area, the Environment Agency / Southwark BC do not currently monitor groundwater levels in the superficial deposits or Basal Sands aquifer.

- A perched water table(s) may exist within the Claygate Member in the south east (near to Crystal Palace). However, there is no monitoring of this unit by either the Environment Agency or Southwark BC.

- A number of potential groundwater flooding mechanisms have been identified. Of significance are those associated with (i) elevated groundwater levels in the Chalk and Thanet Sand Formation aquifers in the Bermondsey and Camberwell area and hydraulic interactions with the superficial deposits, (ii) superficial aquifers not in hydraulic continuity with surface water courses or bedrock aquifers (iii) superficial aquifers in hydraulic continuity with the River Thames. Underground structures including basements and cellars are at most risk from groundwater flooding.

- Areas with increased potential for elevated groundwater have been identified using a number of data sets, including the BGS groundwater flooding susceptibility data set. These appear to be sensible; they are in broad agreement with the identified groundwater flooding mechanisms i.e. they highlight areas of low ground level with permeable bedrock and superficial aquifers.

- Groundwater flooding incident data provided by the Environmental Agency have been assessed and a reasonable correlation exists with areas mapped as having an increased potential for elevated groundwater; the correlation is good in the northern half of Southwark BC and poor in the southern half. However, the incidents in the southern half are thought to be related to poor drainage over impermeable strata i.e. they are not groundwater flooding incidents. Although there is a small chance they are a result of (i) the BGS groundwater flooding susceptibility data set not taking into account groundwater springs / seepages from superficial deposits that flow onto the impermeable London Clay Formation, or (ii) the increased potential for elevated groundwater data set needing to be refined.

- The majority of the Southwark BC area has been identified as potentially unsuitable for infiltration SUDS owing to the impermeable London Clay Formation. Where the London Clay Formation is absent or where River Terrace Deposits exist, enhanced site investigation is required to confirm that infiltration SUDS are suitable.

- The assessment of increased potential for elevated groundwater and suitability for infiltration SUDS could be improved by additional groundwater level / river stage monitoring and the development / use of a numerical groundwater model.
5.2 Recommendations

5.2.1 The following recommendations are made based on the current study. These will allow for a more detailed assessment of increased potential for elevated groundwater and suitability for infiltration SUDS:

- The areas identified as having increased potential for elevated groundwater should be compared with those areas identified as being susceptible to other sources of flooding e.g. fluvial, pluvial and sewer. An integrated understanding of flood risk will be gained through this exercise;
- Southwark BC should provide historic records / routes of any natural surface water courses that no longer exist, if available;
- Acquisition of 1:10,000 scale geological mapping, if it exists, for the areas identified as having an increased potential for elevated groundwater;
- Data identifying properties with basements / cellars should be used to improve the understanding of susceptibility to groundwater flooding;
- Information on mains leakage, foul sewer leakage and groundwater infiltration should be obtained from Thames Water, if available;
- Site investigation reports for historic development sites could be reviewed to obtain additional groundwater level information, to improve the conceptual understanding of the area. Water level information on BGS borehole logs will be another source of information;
- Monitoring boreholes should be installed in the superficial deposits and the Lambeth Group and Thanet Sands bedrock aquifers in the northern half of the Southwark BC, particularly in the Bermondsey and Camberwell area. These monitoring boreholes should be fitted with automatic level recording equipment for a minimum period of one year and water quality sampling undertaken. At this point a review of the monitoring network should be undertaken and an update on potential for elevated groundwater analysis and infiltration SUDS guidance provided.
- Long term (and continuous) river stage monitoring data should also be collected / assessed in the north of the Southwark BC area, where the River Thames has the potential to be in hydraulic continuity with Alluvium and River Terrace Deposits.
- The proposed monitoring boreholes should assist the Environment Agency with water quality and quantity assessments for the next River Basin Management Plan. Therefore, site selection should be agreed with the Environment Agency and the necessity for water quality monitoring agreed;
- Construction of a numerical groundwater model should be considered when at least 3 years of monitoring has been undertaken. The model could then be used as a tool for assessing the impact of infiltration SUDS, other water management options, groundwater abstraction and climate change on groundwater levels within the aquifers.
- Once a more detailed assessment has been undertaken, identify mitigation measures to counteract the potential for elevated groundwater. For example, it is possible that groundwater resources in the River Terrace Deposits could be utilised (perhaps by the water company) to improve the capacity of the aquifer to receive rainfall recharge. This could reduce the overall flood risk.
6 References

The increased Potential for Elevated Groundwater map shows those areas within the London Boroughs where there is an increased potential for groundwater to rise sufficiently to interact with the ground surface or be within 2m of the ground surface. Such groundwater rise could lead to the following:

- Flooding of basements of buildings below ground level;
- Flooding of buried services or other assets below ground level;
- Inundation of farmland, roads, commercial, residential and amenity areas;
- Flooding of ground floors of buildings above ground level; and
- Overflowing of sewers and drains

2. Incident records shown are generally unconfirmed and may include issues such as water main bursts or non-groundwater related problems.

3. Areas not shown to have increased potential for elevated groundwater should be considered to have a low potential for elevated groundwater. Lack of information does not imply 'no potential' of elevated groundwater in that area.

Infiltration SUDS Suitability Map

This map forms an approximate guide to Infiltration SUDS Suitability. However, for all new developments, site investigation is required to confirm local geology, depth to groundwater and infiltration rates.

Legend
- Southwark Borough Council
- EA Groundwater Source Protection Zone
- Inner Zone
- Outer Zone
- Historic Landfill Site
- Infiltration SUDS Suitability
  - Infiltration SUDS potentially suitable
  - Infiltration SUDS potentially unsuitable
  - Infiltration SUDS Suitability Uncertain - Site investigation required

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Scale at A3 1:40,000
Date 22/03/2011
Drawn by C.Woolhouse
Approved by S.Cox

London Borough of Southwark

Surface Water Management Plan

Consultants
URS / Scott Wilson
6 - 8 Greatcoat Place
SW1P 1PL

Drain London Programme Board Members

FIGURE 4