Table 1 - Summary of SUDS Techniques

Technique	Description	Management Train Suitability						Water quantity				Water quality								Environmental benefits		
		Prevention	Conveyance	Pre-treatment	Source control	Site control	Regional control	Conveyance	Detention	Infiltration	Water	Sedimentation	Filtration	Adsorption	Biodegradation	volatilisation	precipitation	Uptake by plants	Nitrification	Aesthetics	Amenity	Ecology
Water butts, site layout & management	Good housekeeping and good design practices.	○	●		○			●	●	○	●	●	●	●	●	●	●	●	●	●	●	●
Pervious pavements	Allow inflow of rainwater into underlying construction/soil.	○			○	●			○	○	●	○	○	○	○	○				●	●	●
Filter drain	Linear drains/trenches filled with a permeable material, often with a perforated pipe in the base of the trench.		○		○	●		○	○				○ ○	○	○	○						
Filter strips	Vegetated strips of gently sloping ground designed to drain water evenly from impermeable areas and filter out silt and other articulates.			○	○			●	●	●		○	○	○	○					●	●	●
Swales	Shallow vegetated channels that conduct and/or retain water (and can permit infiltration when un-lined). The vegetation filters particulates.		○		○	○		○	○	●		○	○	○	○			●		●	●	●
Ponds	Depressions used for storing and treating water. They have a permanent pool and bank side emergent and aquatic vegetation.					○	○		○	●	○	○	○	○	○	○	○	○	○	○	○	○
Wetlands	As ponds, but the runoff flows slowly but continuously through aquatic vegetation that attenuates and filters the flow. Shallower than ponds.		●			○	○	●	○	●	○	○	○	○	○	○	○	○	○	○	○	○
Detention basin	Dry depressions designed to store water fro a specified retention time.					○	○		○			○	●	●	○			●		●	●	●
Soakaways	Sub-surface structures that store and dispose of water via infiltration.				○					○			○	○	○							
Infiltration trenches	As filter drains, but allowing infiltration through trench base and sides.		●		○	○		●	○	○			○	○	○	○						
Infiltration basins	Depressions that's store and dispose of water via infiltration.					○	○		○	○			○	○	○	○				●	●	●
Green roofs	Vegetated roofs that reduce runoff volume and rate.	○		○	○				○				○	○	○	○	○	○	○	○	●	○
Bioretention areas	Vegetated areas for collecting and treating water before discharge downstream, or to the ground via infiltration.				○	○			○	○		○	○	○	○	○	○	○	○	○	○	○
Sand filters	Treatment devices using sand beds as filter media.			○		○	●		○	●			○	○	○	○	○					
Silt removal devices	Manhole and/or proprietary devices to remove silt.			○								○										
Pipes, subsurface storage	Conduits and their accessories as conveyance measures and/or storage. Water quality can be targeted using sedimentation and filter media.		○			○		○	○			●	●									

Key to symbols ● some opportunities, subject to design ○ High/primary process

6.5 SUDS Selection Criteria

The appropriate selection of a SUDS scheme for this development is dependent upon the factors listed in Table 2 below. These characteristics are then considered against the available techniques as illustrated in Table 3 so that an assessment of the suitability of each can be made.

Table 2 - Site Specific Characteristics

Category	Site characteristics
Proposed land use	Residential
Soil type	Kempton Park Gravel, London Clay
Area draining to SUDS components	291m2
Minimum depth to water table	To be confirmed
Site slope	Flat
Available head	To be confirmed
Available space	Low (communal garden)
Water quality treatment potential	Cathpits, gullies and cut-off valve to all hydrobrake chambers.
Hydraulic control	There surface water will be discharged at Greenfield runoff rates; 5.0 l/s.
Maintenance	Desilting and emptying of catchpits and gullies every six months
Community acceptability	High
Cost	Low cost if possible
Habitat creation potential	Low

Table 3 - SUDS Selection Factors

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SUDS GROUP	TECHNIQUE	Residential	Permeable soils	0-2 ha draining to single SUDS component	Min depth to water table 0-1m	Site slope 0-5%	Available head 0-1m	Available space low	Water Quality Treatment Potential: Total suspended solids removal	Heavy metals removal	Nutrient removal	Bacteria removal	Capacity to treat fine suspended sediments and dissolved pollutants	Hydraulic Control: Runoff Volume Reduction	0.5 ([illegible])	0.1-0.2 ([illegible])	0.01 ([illegible])	Maintenance	Community acceptability	Cost	Habitat creation potential
Retention	Retention Pond	Y	Y	Y	Y	Y	Y	N	H	M	M	M	H	L	H	H	H	M	H	M	H
	[redacted]																				
Wetland	Shallow Wetland	Y	Y	Y	Y	Y	Y	N	H	M	H	M	H	L	H	M	L	H	H	H	H
	Extended detention wetland	Y	Y	Y	Y	Y	Y	N	H	M	H	M	H	L	H	M	L	H	H	H	H
	Pond/wetland	Y	Y	Y	Y	Y	Y	N	H	M	H	M	H	L	H	M	L	H	H	H	H
	Submerged gravel/wetland	Y	Y	Y	Y	Y	Y	N	H	M	H	M	H	L	H	M	L	M	L	H	M
	Wetland channel	Y	Y	Y	Y	Y	Y	N	H	M	H	M	H	L	H	M	L	H	H	H	H
Filtration	Surface sand filter	Y	Y	Y	Y	Y	N	N	H	H	H	M	H	L	H	M	L	M	L	H	M
	Sub-surface sand filter	Y	Y	Y	Y	Y	N	Y	H	H	H	M	H	L	H	M	L	M	L	H	L
	Perimeter sand filter	N	Y	Y	Y	Y	Y	Y	H	H	H	M	H	L	H	M	L	M	L	H	L
	Bioretention/ filter strip	Y	Y	Y	Y	Y	Y	N	H	H	H	M	H	L	H	M	L	H	H	M	H
	Filter trench	Y	Y	Y	Y	Y	Y	Y	H	H	H	M	H	L	H	M	L	M	M	M	L
Detention	Detention basin	Y	Y	Y	Y	Y	N	N	M	M	L	L	L	L	H	H	H	L	H	L	M
Open channels	Conveyance swale	Y	Y	Y	Y	Y	Y	N	H	M	M	M	H	M	H	H	H	L	M	L	M
	Enhanced dry swale	Y	Y	Y	Y	Y	Y	N	H	H	H	M	H	M	H	H	H	L	M	M	M
	Enhanced wet swale	Y	Y	Y	Y	Y	Y	N	H	H	M	H	H	L	H	H	H	M	M	M	H
Source	Green roof	Y	Y	Y	Y	Y	Y	Y	NA	NA	NA	NA	H	H	H	H	L	H	H	H	H
	[redacted]																				

6.6.2 Pervious Pavements

Pervious pavements provide a pavement suitable for proposed hard paved courtyard which allows rainwater to infiltrate through the surface into the underlying layers. Pervious pavements with aggregate sub bases provide good water quality treatment. In this instance the pervious pavement will have a tanked sub-base, in order to attenuate the surface water runoff prior to discharge through the hydrobrake. The proposed pervious pavements are to $10m^3$ of attenuation volume.

Key Design Criteria

- Pervious surface and sub-base to be structurally designed for site purpose and design vehicular loading.
- Surface infiltration rate should normally be an order of magnitude greater than the design rainfall intensity.
- Temporary subsurface storage volume to meet requirements for infiltration and/or controlled discharge.
- Geotextile may be specified as a filtration treatment component near the top of the structure.
- Soil and other material must be prevented from contaminating the pavement surface and sub-structure.

Table 6 below outlines the advantages and disadvantages of this technique.

Table 5 - Pervious Pavement Summary Sheet

ADVANTAGES	PERFORMANCE
• Effective in removing urban runoff pollutants. • Lined systems can be used where infiltration is not desirable, or where soil integrity would be compromised. • Significant reduction in volume and rate of surface runoff • Suitable for installation in high density development. • Good retrofit capability. • No additional land take, allows dual use of space. • Low maintenance. • Removes need for gully pots and manholes. • Eliminates surface ponding and surface ice. • Good community acceptability. **DISADVANTAGES** • Cannot be used where large sediment loads may be washed/carried onto the surface. • In the UK, current practice is to use on highways with low traffic volumes, low axle loads and speeds of less than 30mph. • Risk of long-term clogging and weed growth if poorly maintained.	Peak flow reduction: Good Volume reduction: Good Water quality treatment: Good Amenity potential: Poor Ecology potential: Poor **TREATMENT TRAIN SUITABILITY** Source control: Yes Conveyance: No Site system: Yes Regional system: No **SITE SUITABILITY** Residential: Yes Commercial/industrial: Yes High density: Yes Retrofit: Yes Contaminated sites/sites above vulnerable groundwater (with liner) Yes **COST IMPLICATIONS** Land-take: High Capital cost: Medium (Net capital cost: Low) Maintenance cost: Medium **POLLUTANT REMOVAL** Total suspended solids: High Nutrients: High Heavy metals: High
KEY MAINTENANCE REQUIREMENTS:	
• Sweeping • Regular brushing and vacuuming.	

6.7 Assessment of Appropriate SUDS Technique

There is only one viable option available for the disposal of surface water from the site; discharging into the existing sewer. It is recommended that the tanked underground modular storage units or pervious pavements be used for rainwater attenuation.

The developed drainage strategy will enable credits to be awarded under Code for Sustainable Homes environmental assessment criteria.

The proposals for this site would preclude the use any infiltration drainage techniques owing to the prevailing site geology.

7.0 FOUL WATER DRAINAGE

In terms of the foul drainage strategy, it is proposed to discharge 1,0 l/s into the Thames Water public sewer network. The foul water is to drain by gravity from the combined dermacation chamber into the combined sewer located in Magaretta Terrace. The foul water will be pumped directly into the demarcation chamber from the subterranean floors. A 2,5m^3 pump station will be required in order to provide 24hour storage in case of pump failure. + non-return valve to prevent back flow from the sewer

The swimming pool can also be emptied via this combined demarcation chamber, when necessary in the future. The combined demarcation chamber will form a gravity connection into the combined Thames Water sewer running along Magaretta Terrace.

8.0 FLOOD RISK MANAGEMENT MEASURES

The proposed drainage system will be designed to ensure that the surface water generated by a 1 in 100 year plus 30% for climate change storm event will be attenuated by providing 10m^3 of modular within the proposed drainage system. The surface water will discharge at a restricted rate of 5l/s through the proposed combined demarcation chamber.

used to refill swimming pool? filter

Therefore there is no offsite surface water overflow for all storm events until this threshold is exceeded, thus providing a robust flood management regime.

9.0 OFFSITE IMPACTS

It is considered that the proposed drainage designs mean that the surface water and foul flows generated by the proposed development will not have any adverse effect off site.

10.0 RESIDUAL FLOOD RISKS

The only remaining risk following the construction of the proposed systems relates to exceedance of the design criteria. Design flows generated from excess rainfall events will be directed away from buildings. There is perceived to be a very low risk from the development.

Therefore the proposed ground floor Finished Floor Level of 7.000m AOD provides a freeboard of 929mm from the anticipated 1 in 100 year flood event in 2111 of 6.071m AOD. This would provide an adequate threshold to protect against the egress of storm water in extreme weather events. Secondly the all light wells will be constructed with extended physical boundary enclosures with an exposed threshold level set at 6.700m AOD, thus providing a robust mechanism for protection of the proposed dwelling against the egress of surface water in extreme weather events.

11.0 COMPLIANCE WITH CODE FOR SUSTAINABLE HOMES REQUIREMENTS

It is proposed to achieve a level 4 compliance for the development.

11.1 Sur 1 - Management of Surface Water Run-off

11.1.1 Peak rate of runoff

The peak rate of runoff generated by the proposed development will not exceed that of the predevelopment site. Mandatory requirement - achieved.

11.1.2 Volume of Runoff

The volumetric runoff generated by the proposed development will be slightly less than that from the predevelopment site. Mandatory requirement – achieved.

11.2 Sur 2 – Flood Risk

11.2.1 The site is located in Flood Zone 2 and this Flood Risk Assessment shows that there is a very low risk of flooding from any source.

11.3 Points Achieved

The mandatory requirements can be achieved for the site. 1 credits will be achieved for complying with Sur 2.

12.0 RECOMMENDATIONS

It is recommended that the proposed drainage network contained in Appendix F, be implemented for this site in order to ensure that a robust drainage solution is achieved for this site.

13.0 CONCLUSION

The site is in Flood Zone 2 and is at minimal risk of fluvial flooding. The EA have also stated that the site is protected by flood defences and lies on the outline of the extreme flood level; topographical site levels coincide the level of flood protection provided to this area. Further, both the SFRA and the site specific flood risk assessment for this development has not identified potential flood risks for the site that cannot be managed. The following flood management measures are recommended:

- The provision of a 500mm freeboard from adjacent footway levels and 650mm freeboard from the adjacent road levels. This provides a raised threshold that ensures protection of the subterranean habitable space.
- Therefore the proposed ground floor Finished Floor Level of 7.000m AOD provides a freeboard of 929mm from the anticipated 1 in 100 year flood event in 2111 of 6.071m AOD. This would provide an adequate threshold to protect against the egress of storm water in extreme weather events. Secondly the all light wells will be constructed with extended physical boundary enclosures with an exposed threshold level set at 6.700m AOD, thus providing a robust mechanism for protection of the proposed dwelling against the egress of surface water in extreme weather events.
- The use of secondary flood defences to the basement, barriers on doors and the use of flood resilient materials is recommended.
- It is also recommended that the residents of the proposed residential dwelling register their phones (landline and mobile) with the Environment Agency Flood Warning Service, in order to receive flood alerts.

It is proposed that the proposed surface water drainage scheme be implemented in order to provide a robust and sustainable drainage regime to the proposed residential development.

It is considered that the development of this site will not increase flood risk elsewhere.

The site specific Flood Risk Assessment and Preliminary drainage layout is to be submitted to Environmental Agency for their approval as this site lies in Flood Zone 2.

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APPENDIX A

Survey Plan & Site Boundary Plan

APPENDIX G

The SUDS Management Train

The SUDS Management Train

Prevention

The use of good site design and site housekeeping measures to prevent runoff and pollution (eg sweeping to remove surface dust and detritus from car parks), and rainwater reuse/harvesting. Prevention policies should generally be included within the site management plan.

Source Control

Control of runoff at or very near its source (eg soakaways, other infiltration methods, green roofs, pervious pavements).

Site Control

Management of water in a local area or site (eg routing water from building roofs and car parks to a large soakaway, infiltration or detention basin).

Regional Control

Management of runoff from a site or several sites, typically in a balancing pond or wetland.

Runoff Quality Control Processes

There is a range of natural water quality treatment processes that can be exploited within the design of a sustainable drainage system.

Sedimentation

Sedimentation is one of the primary removal mechanisms in SUDS. Most pollution in runoff is attached to sediment particles and therefore removal of sediment results in a significant reduction in pollutant loads. Sedimentation is achieved by reducing flow velocities to a level at which the sediment particles fall out of suspension. Care has to be taken in design to minimise the risk of re-suspension when extreme rainfall events occur.

Filtration and Biofiltration

Pollutants that are conveyed in association with sediment may be filtered from percolating waters. This may occur through trapping within the soil or aggregate matrix, on plants or on geotextile layers within the construction. The location of any filtration will depend upon the internal structure of the particular SUDS technique, for example whether a geotextile layer is near the surface or at the subgrade in a previous surface.

Adsorption

Adsorption occurs when pollutants attach or bind to the surface of soil or aggregate particles. The actual process is complex but tends to be a combination of surface reactions grouped as sorption processes:

Adsorption Pollutants bind to surface of soil/aggregate

Cation exchange Attraction between cations and clay minerals

Chemisorption Solute is incorporated in the structure of a soil/aggregate

Absorption The solute diffuses into the soil/aggregate/organic maters

Change in acidity of runoff can either increase or decrease the adsorption of pollutants by construction materials or soils. Eventually the materials onto which pollutants adsorb will become saturated and thus this method of treatment will stop.

Biodegration

In addition to the physical and chemical processes, which may occur on and within a SUDS technique, biological treatment may also occur. Microbial communities may be established within the ground, using the oxygen within the free-draining materials and the nutrients supplied with the inflows, to degrade organic pollutants such as oils and grease. The level of activity of such bioremediation will be affected by the environmental conditions such as temperature and the supply of oxygen and nutrients. It also depends on the physical conditions within the ground such as the suitability of the materials for colonisation.

Volatilisation

Volatilisation comprises the transfer of a compound from solution in water to the soil atmosphere and then to the general atmosphere. The conversion to a gas or vapour occurs due to heat, reducing pressure, chemical reaction or a combination of these processes. The rate of volatilisation of a compound is controlled by a number of its properties and those of the surrounding soil. In SUDS schemes volatilisation is primarily concerned with organic compounds in petroleum products and pesticides.

Precipitation

This process is the most common mechanism for removing soluble metals. Precipitation involves chemical reactions between pollutants and the soil or aggregate that transform dissolved constituents to form a suspension of particles of insoluble precipitates. Metals are precipitated as hydroxides, sulphides, and carbonates depending on which precipitants are present and the pH level. Precipitation can remove most metals (arsenic, cadmium, chromium III, copper, iron, lead, mercury, nickel, zinc) and many anionic species (phosphates, sulphates, fluorides).

Uptake By Plants

In ponds and wetlands, uptake by plants is an important removal mechanism for nutrients (phosphorous and nitrogen). Metals can also be removed in this manner (although intermittent maintenance is required to remove the plants otherwise the metals will be returned to the water when the plants die). Plants also create suitable conditions for deposition of metals, for example as sulphides the root zone.

Nitrification

Ammonia and ammonium ions can be oxidised by bacteria in the ground to form nitrate, which is a highly soluble form of nitrogen. Nitrate is readily used as a nutrient by plants

Photolysis

The breakdown of organic pollutants by exposure to ultra-violet light.

The removal mechanism appropriate for each pollutant category is presented in the Table below.

Table 3 - removal mechanism appropriate for each pollutant

Pollutant	Removal mechanisms in SUDS
Nutrients Phosphorous, nitrogen	Sedimentation, biodegradation, precipitation, de-nitrification
Sediments Total suspended solids	Sedimentation, filtration
Hydrocarbons TPH, PAH, VOC, MTBE	Biodegradation, photolysis, filtration and adsorption
Metals Lead, copper, cadmium, mercury, zinc, chromium, aluminium	Sedimentation, adsorption, filtration, precipitation, plant uptake
Pesticides	Biodegradation, adsorption, volatilisation
Chlorides	Prevention
Cyanides	Volatilisation, photolysis
Litter	Trapping, removal during routine maintenance
Organic matter, BOD	Filtration, sedimentation, biodegradation

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APPENDIX F

Preliminary Drainage Layout & Site Proposals

ICP SUDS Mean Annual Flood

Input

Return Period (years)	100	Soil	0.300
Area (ha)	0.037	Urban	0.750
SAAR (mm)	600	Region Number	Region 6

Results	l/s
QBAR Rural	0.1
QBAR Urban	0.2
Q100 years	0.4
Q1 year	0.2
Q30 years	0.4
Q100 years	0.4

MAP 17
Surface Water Flooding

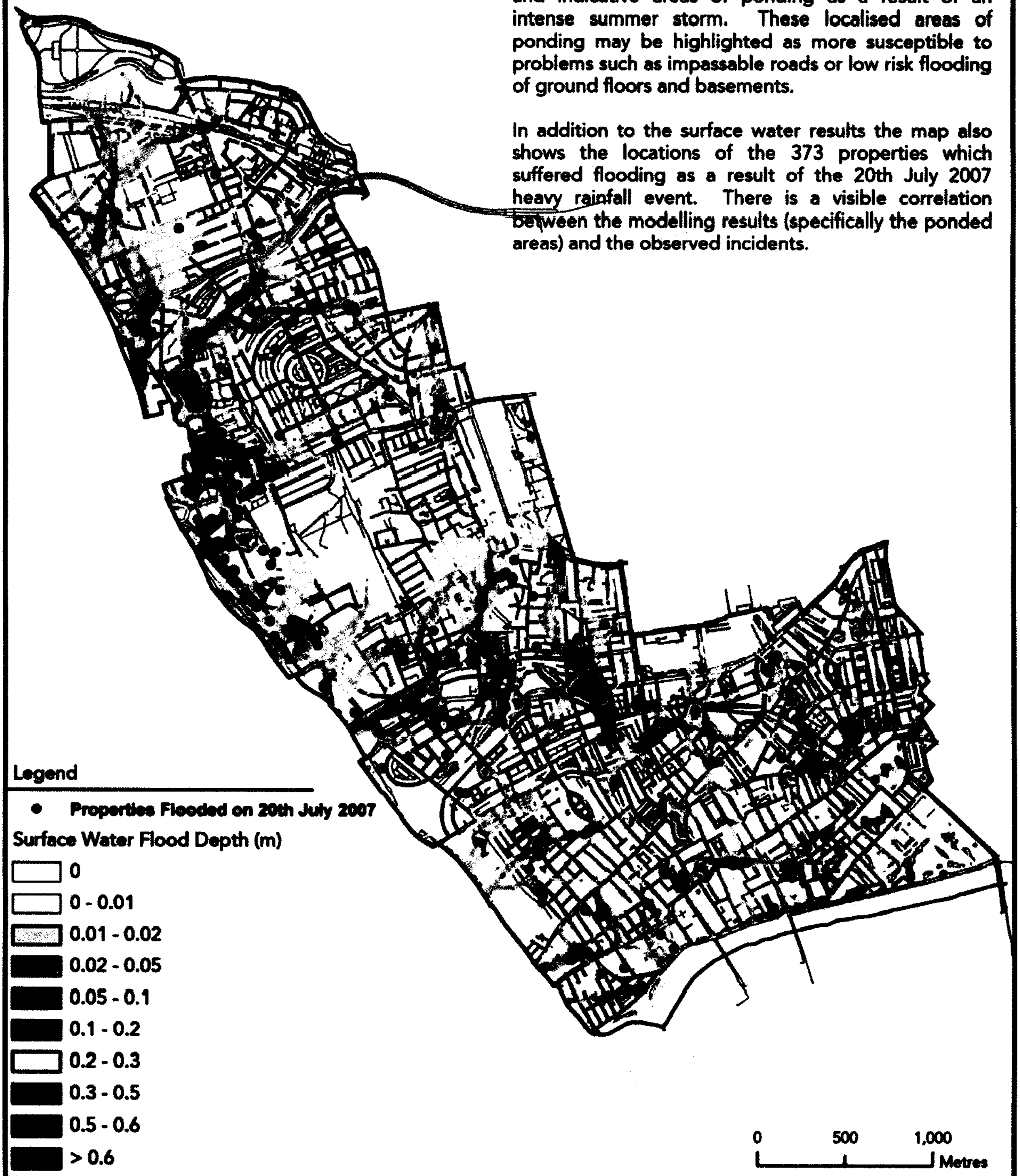
ROYAL BOROUGH OF
KENSINGTON
AND CHELSEA

North

Surface water flooding from an intense summer storm across the natural catchments contributing to the Borough was modelled.

This map shows the indicative surface water flow paths and indicative areas of ponding as a result of an intense summer storm. These localised areas of ponding may be highlighted as more susceptible to problems such as impassable roads or low risk flooding of ground floors and basements.

In addition to the surface water results the map also shows the locations of the 373 properties which suffered flooding as a result of the 20th July 2007 heavy rainfall event. There is a visible correlation between the modelling results (specifically the ponded areas) and the observed incidents.



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MAP 13
Breach Innundation Flood Extent and Depth

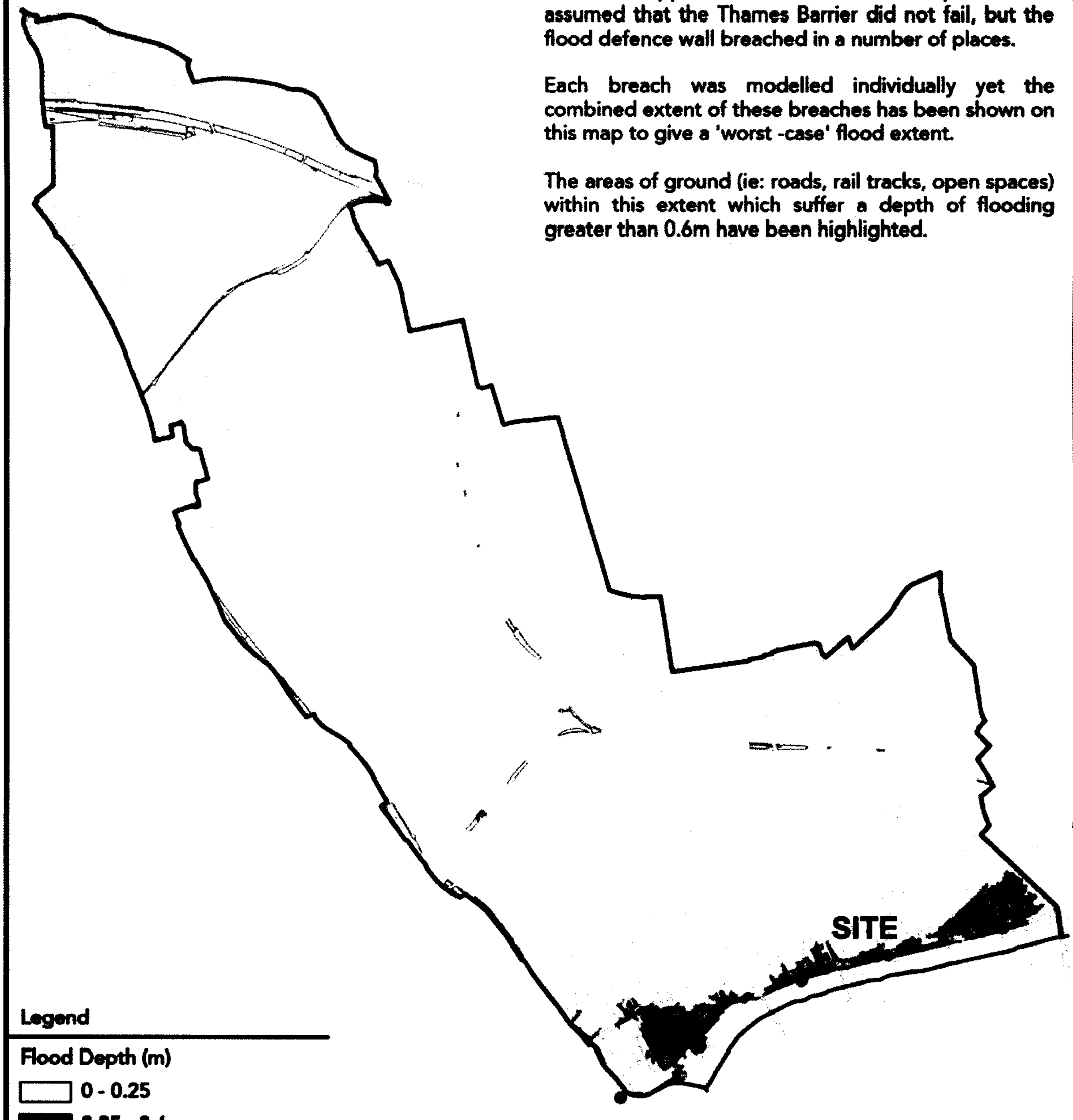
ROYAL BOROUGH OF KENSINGTON AND CHELSEA

North

This area of the River Thames is defended to a high standard with flood walls and the Thames Barrier, therefore the site is only at risk of flooding as a result of these defences failing.
For the mapped breach extents and depths it was assumed that the Thames Barrier did not fail, but the flood defence wall breached in a number of places.

Each breach was modelled individually yet the combined extent of these breaches has been shown on this map to give a 'worst -case' flood extent.

The areas of ground (ie: roads, rail tracks, open spaces) within this extent which suffer a depth of flooding greater than 0.6m have been highlighted.



Legend

Flood Depth (m)

- 0 - 0.25
- 0.25 - 0.6
- >0.6
- Breach Extent
- Breach Locations

0 500 1,000 Metres

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MAP 12
Breach Locations & Flood Defence Conditions

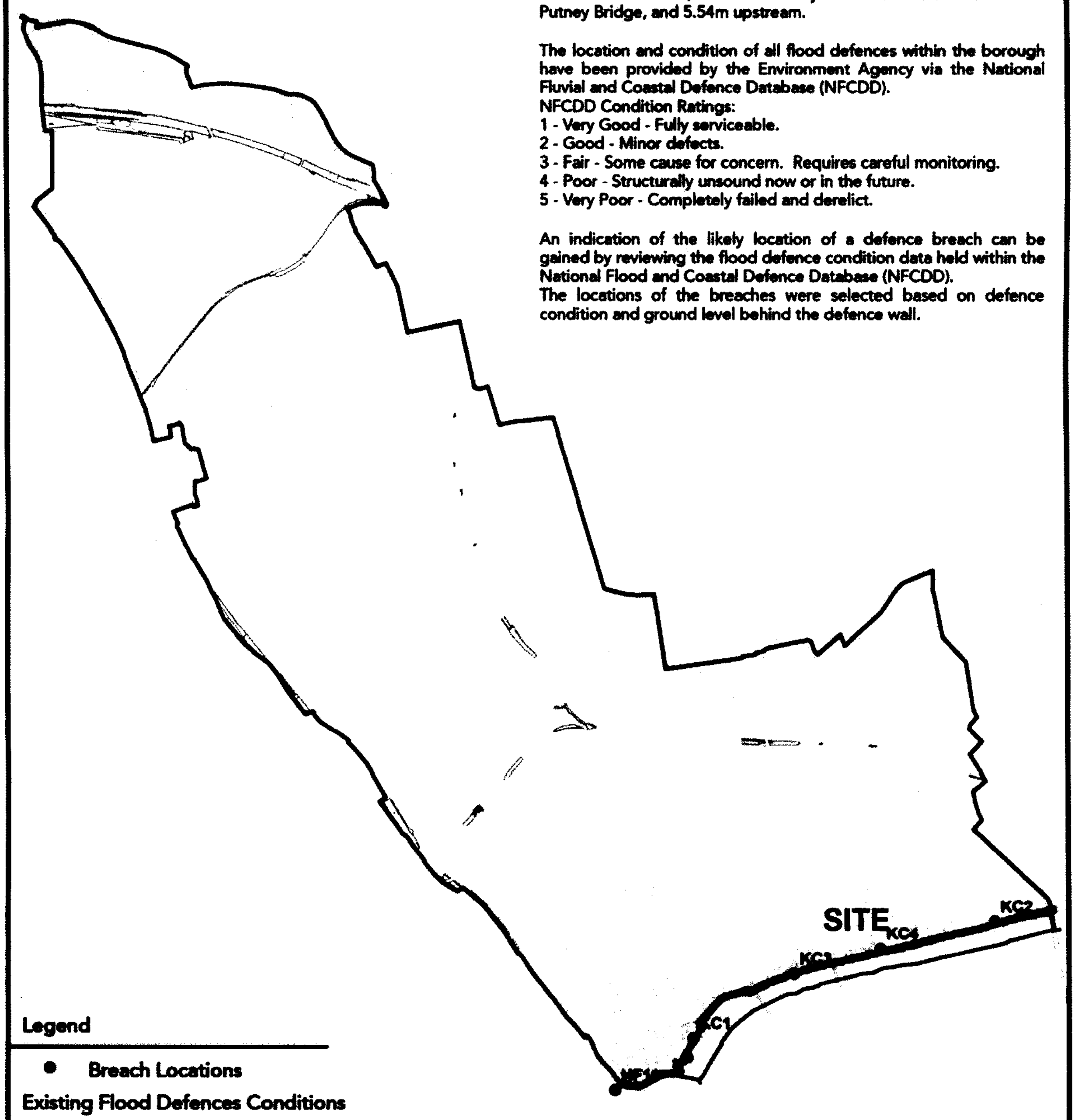
ROYAL BOROUGH OF KENSINGTON AND CHELSEA

North

The Tidal Thames is defended to a 1 in 1000 year standard (protection against an event with a 0.1% chance of occurring each year), by a series of walls, embankments, flood gates and barriers, with the Thames Barrier being the major protection for the study area. The statutory defence level (the level to which the defences must be maintained) within the study area is 5.41m downstream of Putney Bridge, and 5.54m upstream.

The location and condition of all flood defences within the borough have been provided by the Environment Agency via the National Fluvial and Coastal Defence Database (NFCDD).
NFCDD Condition Ratings:
1 - Very Good - Fully serviceable.
2 - Good - Minor defects.
3 - Fair - Some cause for concern. Requires careful monitoring.
4 - Poor - Structurally unsound now or in the future.
5 - Very Poor - Completely failed and derelict.

An indication of the likely location of a defence breach can be gained by reviewing the flood defence condition data held within the National Flood and Coastal Defence Database (NFCDD).
The locations of the breaches were selected based on defence condition and ground level behind the defence wall.



Legend

- Breach Locations

Existing Flood Defences Conditions

Very Good

Good

Fair

0 500 1,000 Metres

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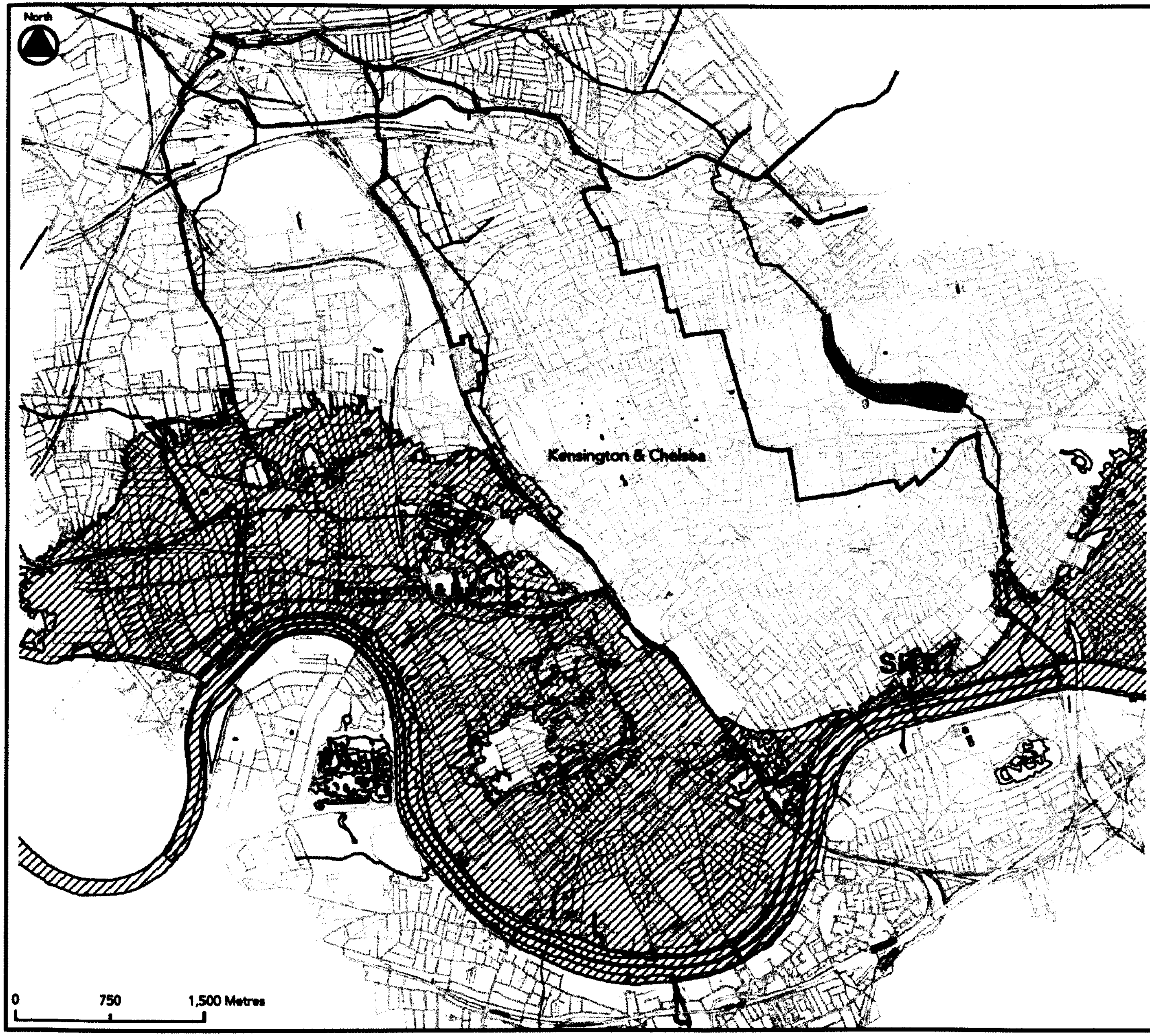

LEGEND

- Rail
- Roads Tracks And Paths
- Water
- Borough Boundary
- Grand Union Canal
- Existing Flood Defences
- The Serpentine
- Lost Rivers
- Flood Zone 3
- Flood Zone 2

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MAP 1

Study Area