OPDC
OLD OAK AND PARK ROYAL DEVELOPMENT CORPORATION

Integrated Water Management Strategy

LOCAL PLAN SUPPORTING STUDY

Draft for Regulation 18 Consultation
4 February 2016

MAYOR OF LONDON

Role of this study

This study has been produced to inform the draft Local Plan and should be read alongside other relevant studies, the draft Local Plan and the London Plan.

Study overview

Document title	**Integrated Water Management Strategy**
Lead author	AECOM Global
Purpose of the study	Review of water infrastructure requirements for water demand, drainage, and flood risk (including OPDC's Strategic Flood Risk Assessment). Provides options and costs for integrated water management.
Stage of production	Draft completed to inform Regulation 18 version of the Local Plan
Key outputs	■ A strategic assessment of current major redevelopment proposals in the Counters Creek catchment highlighting key opportunities and constraints. ■ A strategic level flood risk assessment of the OPDC area. ■ Assessment of baseline water demands, sewage production and rainfall runoff for the development using the OAPF information. Estimates for water demand and sewage and rainfall runoff production for a range of scenarios. ■ Review of the capacity and performance of the existing infrastructure. Information on infrastructure capacity and performance highlighting when and where incapacity will lead to failures in levels of service. ■ Assessment of individual building and communal scale opportunities to sustainably manage potable water, sewage, drainage and flood risk needs of the OPDC area using an integrated approach. Assessment includes the options and options appraisal process; and the preferred strategy. ■ An assessment of the 'smart' technology opportunities to enable scalable, robust and long-term sustainable water management. ■ Report detailing costs, implementation mechanisms and timings for the preferred strategy and how the costs
Key recommendations	■ For water management, a range of options are identified at both strategic and site level for managing surface and storm water run-off, and for disposing of waste water. These include the need for a centralised sustainable drainage system, in addition to site specific measures. ■ For potable water, recommendations include the need for rainwater harvesting and greywater re-use to achieve as close as possible to neutrality in water use.

Relations to other studies	Outputs to inform Utilities and Infrastructure Strategy Outputs to inform and be informed by Green Infrastructure and Open Space Strategy, Public Realm Strategy, and Old Oak Decentralised Energy Strategy.
Next steps	The Strategy is in draft and is available for comment. Necessary revisions will be made following public consultation before the document is finalised to sit alongside the Regulation 19 consultation on the Local Plan. The document will inform the OPDC Infrastructure and Utilities Strategy in 2016 in regard to options for delivering water infrastructure sustainably, cost-effectively and in an integrated way with other infrastructure across the area.

Consultation questions

1. Do you agree with the recommendations of this supporting study? If not, please explain why.

2. Do you agree with the methods used in delivering the recommendations? If not, please set out alternative approaches and why these should be used.

3. Are there any other elements which the supporting study should address? If yes, please define these.

You can provide comments directly through:

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Old Oak Common and Park Royal

Integrated Water Management Strategy

Draft Report

Quality information

Document name	Ref	Prepared for	Prepared by	Date	Reviewed by
Final Draft	Draft 2	OPDC	AECOM	January 2016	Michael Henderson Galo Pinto Carl Pelling

Revision history

Revision	Revision date	Details	Name	Position

Executive Summary

The growth proposed for the Old Oak Common and Park Royal Opportunity Area is of such considerable scale that it will require a step change in the provision of water supply, wastewater treatment and water infrastructure. The extent of water challenges facing the Opportunity Area cannot be overemphasised. They include an acute lack of capacity within the drainage infrastructure, areas of surface water and sewer flooding risk locally and in neighbouring areas, and an increasing deficit of available water to meet demand in an over growing city.

An Integrated Water Management Strategy has been developed to set a framework for how water and wastewater should be managed within the Opportunity Area to move towards a more sustainable new development. The Strategy has been formed around several core objectives:

- To ensure that the rate of wastewater and surface water discharge to the sewer is no greater than it is from the site usage of the Opportunity Area in the present day;
- To minimise the volume of water is discharged to the sewer;
- To manage surface water runoff to a position that would match runoff from the site if it were undeveloped (greenfield);
- To reduce as far as possible the demand for centralised water supply by re-using water resources and wastewater resource on site;
- To deliver these objectives in the most sustainable way bearing in mind the need to ensure the overall viability of the site.

A strategic review of flood risk sources and water infrastructure coverage has been undertaken to determine the baseline constraints and conditions. Further, a water balance exercise was undertaken to determine the water available on the site and the extent of change in water uses and wastewater and surface water generated as a result of the development.

Within the context of these constraints and the water balance, several water management measures have been considered and developed, and this process included input from a range of stakeholders with an influence on how water will be managed and used in the development. The measures were assessed against a range of criteria, covering deliverability as well as sustainability, to arrive at baskets of measures which can meet the core objectives but with a range of different benefits and disbenefits.

The baskets of measures have been developed as ‘strategy options’ and six of these options have been defined in order to ensure flexibility of approach as the masterplanning and detailed infrastructure assessment work progresses for the Opportunity Area.

Of the six potential Strategy options proposed, a preferred solution has been identified and recommendations for how this strategy could be taken forward are presented within this document, including strategy delivery and next technical steps. The output from the Strategy recommendations has been used to draft the water policy elements and water management approach included within the draft Local Plan.

Views are now sought on this consultation version of the Integrated Water Management Strategy, as part of the wider Local Plan consultation, from a range of interested parties to help shape the Strategy next steps.

Contents

1 Strategy Background

1.1 Introduction

1.1.1.1 At the proposed intersection between Cross Rail and HS2, Old Oak Common and Park Royal has been identified as a key Opportunity Area for growth. This thriving new centre will make a major contribution to meeting London's residential and employment needs by providing approximately 25,500 new homes and an indicative 65,000 new jobs over the next 20 to 30 years. This scale of growth will require a step change in utilities infrastructure, and in particular the water infrastructure, needed to ensure the development is delivered in a more sustainable way. Given the age and limited capacity of the existing water infrastructure in the area, there are particular challenges to ensuring a more sustainable supply of water, as well as more sustainable system for the management of wastewater, storm water and flood risk.

1.1.1.2 As well as representing a challenge, the scale of development proposed at Old Oak and Park Royal present a rare opportunity to deliver truly integrated water management; capitalising on the potential to reuse water before it is discharged, and using the principles of water sensitive urban design (WSUD) to shape the fabric of the new development. The development of this Integrated Water Management Strategy ('the Strategy') for Old Oak and Park Royal is therefore vital to set a framework for the delivery of this step change in water infrastructure provision. Identifying opportunities early in the development processes will help to ensure that the strategic infrastructure required to deliver more sustainable water management is appropriately captured in the master plan and ensure that planning policy is developed to enable the delivery in an efficient, coordinated and cost effective way. The Strategy is therefore an important evidence base supporting the development of the Local Plan for the Opportunity Area and the conclusions and recommendations made within this Strategy have been used to develop planning policy within the emerging Local Plan.

1.2 Strategy Aims and Governance

1.2.1.1 This strategy and its objectives have been developed in collaboration and consultation with key partners integral to the delivery and management of water infrastructure for Old Oak and Park Royal. A steering group has overseen the Strategy development made up of:

- the Greater London Authority (GLA);
- the Old Oak and Park Royal Development Corporation (OPDC);
- Thames Water Utilities Ltd;
- the Environment Agency;
- the London Borough of Brent;
- the London Borough of Hammersmith and Fulham (LBHF);
- the London Borough of Ealing; and
- the London Borough Kensington and Chelsea.

1.2.1.2 The main high level aims of the Strategy as identified in consultation with the Steering Group are to:

- Embed sustainable water management principles into the Old Oak Common and Park Royal regeneration masterplan;
- Set the framework for delivering an exemplary, integrated approach to managing water supply, waste water and flood risk to guide future infrastructure delivery; and
- Set a framework which demonstrates workable solutions to the capacity limitations and water challenges facing the development.

1.2.1.3 In delivering these aims, a series of water management and sustainability objectives have been set by the Steering Group. These objectives are included within Section 5 of this Strategy document.

1.2.1.4 In addition to the steering group governance, a wider stakeholder workshop was held during the Strategy development to ensure it captured and considered all potential water management options and that the approach to assessing options was appropriate.

2 Site Context and Proposals

2.1.1.1 Old Oak Common and Park Royal are located at the meeting point of two major strategic growth corridors: the London- Luton - Bedford Growth Corridor and the Western Wedge. The area's wider context points to the true potential of the area positioned half way between Heathrow and Central London.

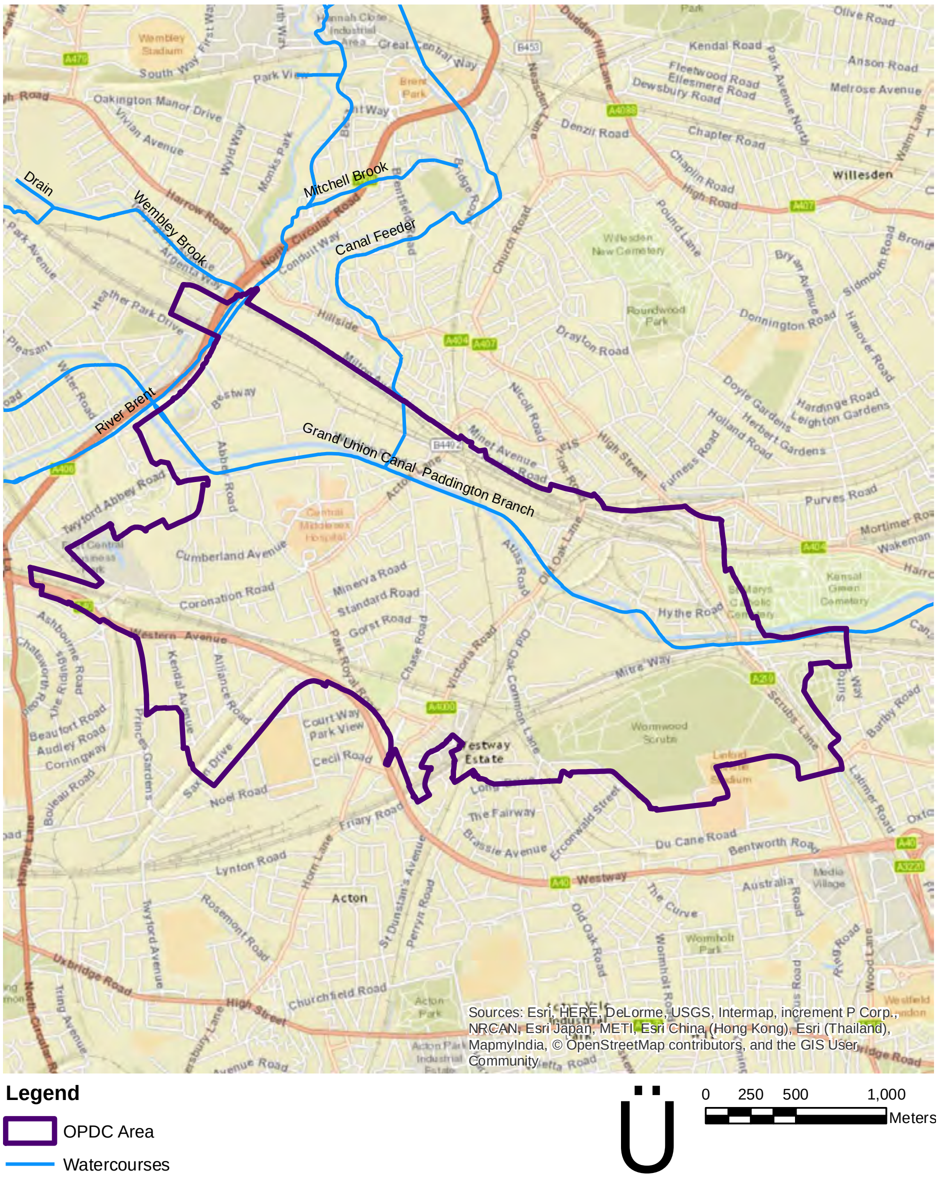


Figure 2-1: Location context of the Old Oak and Park Royal development area

2.1.1.2 The area provides valuable development capacity to accommodate London's rapidly expanding population and to develop a range of uses, including the higher education sector, creative industries, entertainment and retail, which could help London maintain its world city status.

2.1.1.3 The HS2/Crossrail interchange at Old Oak Common will fundamentally change the development potential of the area and the role it plays in its wider London context. The new interchange could become a destination in itself and the heart of a new piece of city that could benefit from a canal side setting and proximity to one of the largest park spaces in London at Wormwood Scrubs. This could in turn benefit the core of the Park Royal industrial estate which will be retained and developed to build on its role as London's premier industrial location of the national economy.

2.2 Existing Site

2.2.1 Land Use

2.2.1.1 Although small pockets of residential property are situated within the Opportunity Areas, Park Royal and Old Oak Common are dominated by industrial and commercial land uses. Park Royal in particular is designated as a Strategic Industrial Location (SIL), housing approximately 2,000 businesses with 30,000 employees.

2.2.1.2 Park Royal and Old Oak Common are well connected with transport links, with the Great Western Main Line (GWML), West Coast Main Line (WCML), London Overground (LO) and London Underground (LU) lines, Central Line and Bakerloo Line all pass through the Opportunity Area. This transport network will be further expanded with the planned development of the HS2 lines and station as well as Crossrail lines.

2.2.1.3 In addition to the developed areas, Wormwood Scrubs makes up a significant proportion of the Old Oak area providing valuable amenity and ecological space.

2.2.2 Water Environment

2.2.2.1 Surface Water

2.2.2.2 The River Brent is the only significant natural watercourse located within the Opportunity Area. The river forms the north-west boundary of the Park Royal. The Grand Union Canal (Paddington Branch) runs through the centre of the Opportunity Area and is a key feature influencing topography and movement of surface water (see Figure 2-1).

2.2.2.3 The general topography within the Opportunity Areas slopes from north to south. The local topography results in three natural hydrological drainage catchments as shown in Figure 2-2. The majority of Park Royal naturally drains in a north-westerly direction towards the River Brent. The southern section of Park Royal drains to the south into what was known as the Stamford Brook (now culverted and incorporated into the Counters Creek catchment). The Old Oak section of the Opportunity Area drains into the previously open watercourse the Counters Creek (also culverted and incorporated into the sewer system).

2.2.2.4 The natural topography and how the area drains has been artificially modified by infrastructure development (e.g. excavation of the siding for the Great Western Main Line (GWML) and the creation of the Grand Union Canal) and reconfiguration of the sewer system where previously open watercourses have been incorporated into the combined sewer system (Stamford Brook and Counters Creek).

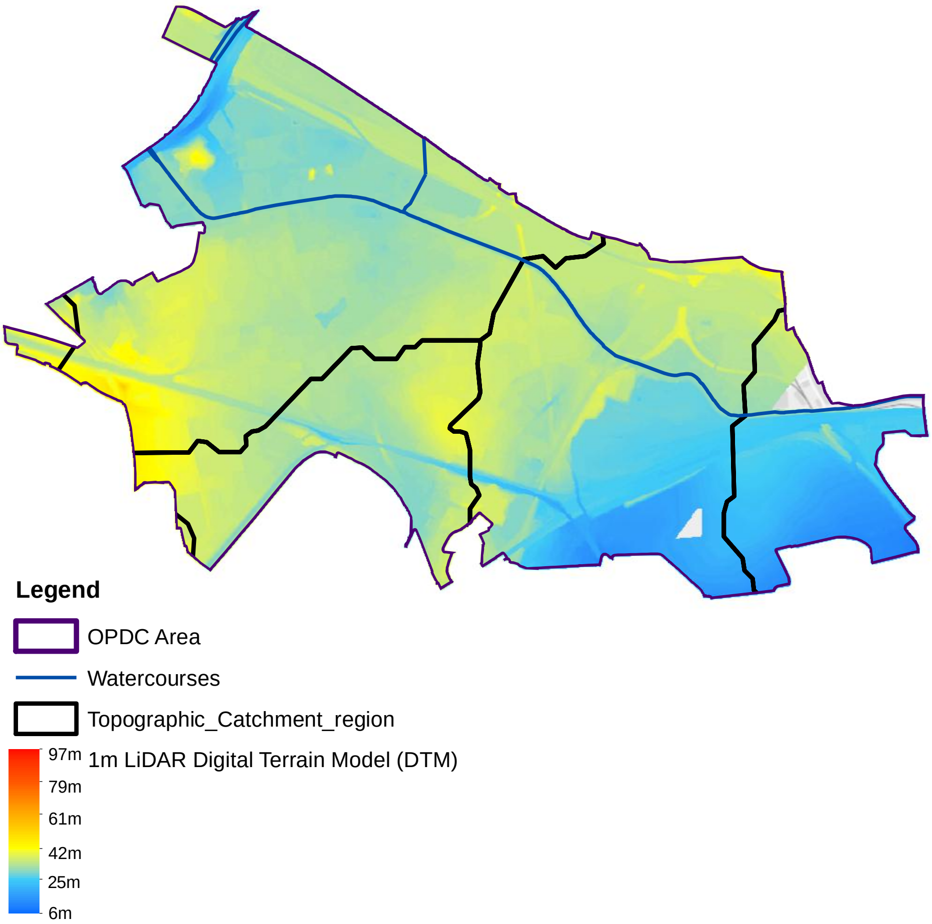


Figure 2-2: Surface topography and natural hydrological catchments across the Opportunity Areas

2.2.2.5 Geology and Groundwater

2.2.2.6 The Opportunity Area lies almost solely on a bedrock of London Clay, with limited superficial deposits of Alluvium and Gravel in the north-west corner of the development area boundary associated with the River Brent, as shown in Figure 2-3. London Clay is a low permeability geological stratum.

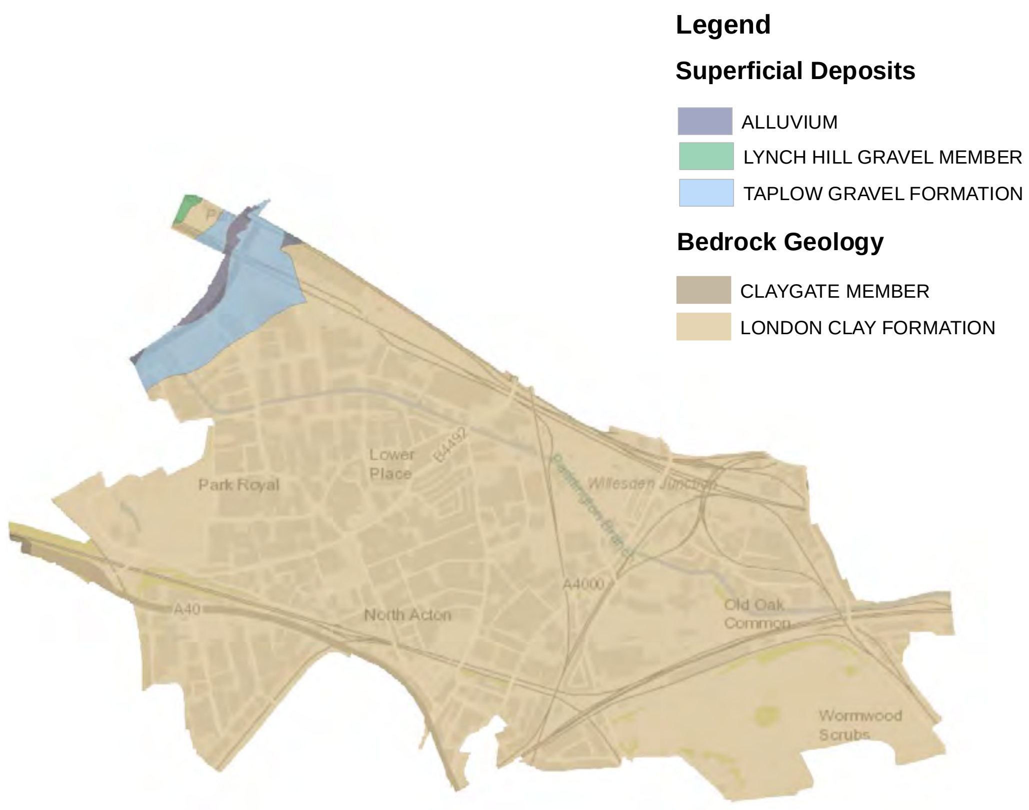


Figure 2-3: Bedrock and superficial geology

2.3 Proposed Development

2.3.1 Old Oak Common

2.3.1.1 Major new development will be focused at Old Oak Common, which is proposed to be a high density mixed-use development accommodating approximately 25,500 new homes and an indicative 65,000 new jobs. An indicative layout of the current master planning proposals for this part of the Opportunity Area is shown in Figure 2-4.

Figure 2-4 - Old Oak indicative masterplan, Old Oak and park Royal OAPF (2015)

2.3.2 Park Royal

2.3.2.1 As part of the regeneration, Park Royal is proposed to remain as a SIL, with the majority of existing businesses retained. In addition, the Park Royal development will provide approximately 10,000 new employment opportunities. The primary area for this development will be at the site of the HS2 construction sites following their release upon completion of the project. The current preferred option is for site re-development as an industrial business park, incorporating 125,750 m2 of new floor space.

2.3.2.2 In the centre of Park Royal, the existing retail area is planned to be enhanced and expanded to become a local hub for residents and businesses. In addition, 1,500 new homes will be constructed to the west of Park Royal and additional employment opportunities created through regeneration and densification of the existing land use.

2.3.3 Wider Development Proposals

2.3.3.1 In addition to the growth proposed at Park Royal and Old Oak, several other Opportunity Areas are proposed within west, and north-west London which will share key parts of the same limited capacity water infrastructure. The Opportunity Area Planning Frameworks (OAPF) for each area have been reviewed and compared to growth within Old Oak and Park Royal to set the context of additional water demand and wastewater discharge volumes.

2.3.3.2 The OAPFs provide large scale redevelopment zones, with these areas likely to result in extensive increases in water demand and wastewater discharge. Table 2-1 summarises the growth projections for each of the OAPFs likely to share the same drainage and water supply infrastructure as Park Royal and Old Oak.

Table 2-1 Opportunity Area Planning Frameworks within north-west London[1]

OAPF	Overview
Wembley	• 2,500 new homes • 15,000 jobs • 30,000 m^2 of retail • New residential district, expanded and redeveloped industrial sites and business parks, civic centre, expanded town centre with Wembley Stadium at the centre
Kensal Canalside (Gasworks)	• 3,500 new homes • 2,000 new jobs • Mixed use development, crossrail station, residential, commercial, workshops, small offices and studios, creating a creative and cultural hub
White City	• 6,000 new jobs • 10,000 new homes • Mixed use – creative, academic, technology and small businesses, and investment in the metropolitan town centre
Earls Court and West Kensington	• 7,500 new homes • 9,500 new jobs • New urban quarter with residential and mixed use development, replacing the old Earls Court Exhibition centre

2.3.3.3 Water demand and wastewater discharge calculations for the wider Opportunity Areas are presented in Appendix A. The growth across all Opportunity Areas sharing the same drainage and water supply infrastructure is estimated to result in an increase in water demand of over 13 million litres per day and a commensurate increase in wastewater generation. Growth within Old Oak and Park Royal is expected to contribute approximately 56% of the calculated increase in residential demand and discharge, and between 70% and 80% of the employment based demand and discharge.

[1] Source: http://www.futureoflondon.org.uk/2015/02/13/londons-opportunity-areas/

3 Water Challenges

3.1 Drainage and Wastewater

3.1.1.1 The pressure on the drainage infrastructure within this region of London is particularly prominent. All of Old Oak and the majority of Park Royal are connected to the Counters Creek sewer sub-catchment of the larger Beckton wastewater treatment catchment in north London. The remainder of Park Royal drains to the Mogden wastewater treatment catchment to the west and south west of the site.

3.1.1.2 The Counters Creek catchment is a combined sewer system (transmitting both foul wastewater and surface water) suffering from a lack of capacity which has resulted in sewer flooding of several properties during rainfall events which would normally be expected to be accommodated by the sewer system. The Counters Creek Storm Relief Sewer is proposed to reduce the frequency and extent of sewer flooding to these properties in the catchment. The scheme is being designed to provide sewer flood risk reduction to Thames Water's current design standards and is designed to alleviate the issue experienced at existing properties. It is not designed to accommodate additional foul flows or surface water runoff from new areas of development within the catchment. The potential for the option of increasing the capacity of the scheme has been considered within this Strategy.

3.1.1.3 This highlights the limited capacity of the sewers within the catchment to accept additional foul flows and surface water runoff from new development. In many cases there is no capacity for any increase in combined flow volumes during rainfall events without resulting in an unacceptable risk of flooding downstream and adjacent development. Sewer flooding and surface water flooding are therefore two of the key water management and flood risk concerns within this area of West London. In acknowledgement of this, Thames Water expect all development to reduce peak combined flow off their site as part of development so that it is no greater than pre-development discharges as a minimum.

3.1.1.4 Without mitigation, the proposed development at Old Oak and Park Royal would result in significant increase in foul flows to the Counters Creek system. The potential impact of this would be exacerbated by the unmitigated development of other identified Opportunity Areas within the drainage catchment where capacity is severely limited (see Appendix A). This has the potential to result in significant flood risk both within Old Oak and Park Royal as well as further downstream in the catchment if peak flows are not managed from all potential development sites. This is a significant driver to ensure that the volume and rate of wastewater discharge (both foul and surface water) is minimised as far as possible within the development.

3.2 Water Resources

3.2.1.1 Water resources within London are (and will continue to be) subject to significant levels of stress. This arises from several pressures including effects of climate change on raw resources, leakage, environmental protection and finite capacity within raw resources. With central planning projections anticipating a 37 per cent increase in London's population from 2011 to 2050, with a resident population of 11.3 million by mid-century2 population growth and density will exacerbate these constraints.

3.2.1.2 Thames Water manages the water supply in London as a single 'resource zone'; that is, all customers in this zone share the same water resources and hence share the balance of supply and demand. Under the current assessment of water resource availability for the next 25 years3, the London Water Resource Zone is predicted to have an increasing deficit in available supply (demand is greater than supply) growing from a deficit of 59.4 million litres a day currently to 415.9 million litres a day by 2040. This highlights the significant pressure that London's water resource base is under in order to continue to supply water to meet the growth that is planned across the City.

[2] London 2050 plan
[3] Thames Water - Resources Management Plan 2015 to 2040 (2015)

3.2.1.3 Thames Water has developed a plan for removing this deficit through a combination of measures to tackle leakage, manage (and reduce) water demand and implement new water supply schemes. The plan to manage the deficit is reliant on significant demand reduction measures from existing property and highlights the need for new developments to minimise water use and help identify innovative solutions to delivering alternative supplies. This is reflected in water use and supply policies within the London Plan:

- Promoting the use of rainwater harvesting and using dual potable and grey water recycling systems, where they are energy and cost-effective; and
- Requiring development to minimise the use of mains water by incorporating water saving measures and equipment and designing residential development so that mains water consumption would meet a target of 105 litres or less per head per day.

3.3 Infrastructure Coverage

3.3.1.1 GIS layers of the existing water, sewer and flood risk management infrastructure within the Opportunity Area have been provided by key stakeholders, including Thames Water, the Canal and Rivers Trust and Lead Local Flood Authorities. These datasets have been consolidated and a GIS infrastructure register developed. This is presented with in Appendix B. An excel version of the register has also been developed and separately delivered as a part of this study. A summary of the existing water and wastewater infrastructure in the Opportunity Area is shown in Figure 3-1 and described in more detail below.

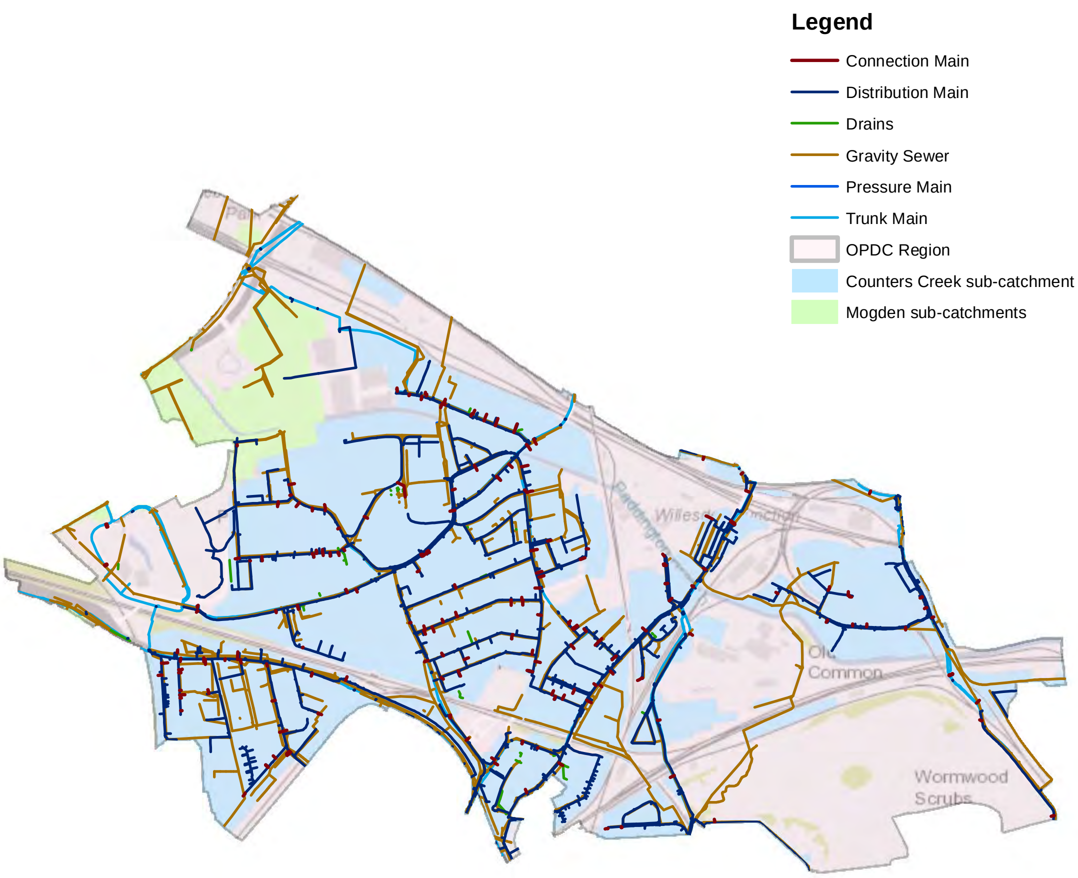


Figure 3-1 – Existing water and wastewater infrastructure

3.3.2 Water supply infrastructure

3.3.2.1 There are several trunk and distribution mains which supply water to properties throughout the area. In general, Park Royal is supported by a dense network of underground pipework. However, there is less existing infrastructure within Old Oak Common, reflective of the low density nature of the current land uses. In order to support the residential and commercial re-development currently proposed within the area masterplan, the installation of comprehensive new water distribution infrastructure is likely to be required.

3.3.3 Wastewater infrastructure

3.3.3.1 A small area of the north-western extent of Park Royal does not drain into the Counters Creek system. This area forms a part of the Mogden sub-catchment with foul flows discharging to the Mogden Wastewater Treatment Works (WwTW) and surface water from the Opportunity Area discharging to the River Brent

3.3.3.2 The coverage of the existing sewer infrastructure follows a similar pattern to the water supply infrastructure, with relatively comprehensive coverage over Park Royal, and more sparse coverage over Old Oak Common. Extensive new sewage and drainage infrastructure will be required to be delivered to service the planned development in this area.

3.4 Flood Risk

3.4.1.1 A Strategic Level Flood Risk Assessment has been undertaken for Old Oak and Park Royal and is reported within Appendix C. Overall, flood risk to the Opportunity Area is relatively low for the majority of flood risk sources.

3.4.1.2 Only a small area of the site, to the north west of Park Royal is affected by fluvial flooding associated with the River Brent. Existing property is currently not located within this area of fluvial flood risk.

3.4.1.3 The Strategic Flood Risk Assessment demonstrates that the main source of flood risk directly affecting the Opportunity Area is surface water flooding. This occurs as surface water ponding or overland flow during high intensity rainfall events as rainwater is unable to drain into the sewer system. This flooding is partly explained by the culverting, and subsequent adoption into the combined sewer system of the previously open watercourses. The rail and road infrastructure (often set at different levels) also creates additional barriers to overland flow leading to areas of ponding.

3.4.1.4 Historical records also indicate that sewer flooding has occurred in a number of locations in the Opportunity Area; these are largely confined to the central areas of Park Royal.

3.4.1.5 A combination of fluvial flooding, surface water flood risk, drainage capacity and sewer flooding creates localised areas of higher flood risk which need to be factored into the more detailed stages of masterplanning and subsequent planning applications for development plots. Management of excess water within three areas also represents an opportunity for storage and re-use and provision of dispersed flood storage to meet the water management aims derived for the Strategy (see section 6). The higher flood risk areas are highlighted in Figure 3-2. Recommendations for managing and mitigating risk within these areas are discussed in the context of the various strategy options developed and detailed in section 6 of this report. Full details are provided in Appendix C.

Figure 3-2: Higher flood risk areas within Old Oak and Park Royal

3.5 Water Challenges Summary

3.5.1.1 The key water challenges shaping the Strategy and its core objectives can be summarised as:

- An acute clack of capacity in the sewer network to accommodate additional foul flows without increasing sewer flood risk downstream;
- A growing deficit in available water supply to meet demand, exacerbated by climate change and a rapidly increasing population in London;
- A lack of suitable water supply and wastewater infrastructure to serve the quantum of growth proposed across the Opportunity Area; and
- Areas of localised surface water flood risk which could be exacerbated by the scale and location of proposed development if not sufficiently mitigated.

4 Opportunity Area Water Cycle

4.1 Annual Water Flows

4.1.1.1 An annual water balance model has been developed for the Opportunity Areas to characterise and quantify the water cycle flows anticipated from the proposed development; this process has been undertaken to determine the available water during average conditions over the course of a year as well as determining the demand for water and generation of daily wastewater flows from new development.

4.1.1.2 For the purposes of this exercise, the OPDC development boundary was taken as the system boundary, and all flows are estimated over an annual timescale. The model estimates flows by building up from plot level, to simulate the area–wide balance between input and output of water. The two predominant inflows to the urban cycle are:

- The natural hydrological flows, which originate as rainfall and exit the system through groundwater infiltration, evapotranspiration and urban runoff.
- The centralised water supply, which is imported from outside the area boundary, and consumed or discharged through the wastewater system.

4.1.1.3 Each of the flows included within the water balance is briefly described in Table 4-1 and a schematic of how the flows contribute to the pre-development (existing condition) water cycle on site is presented in Figure 4-1 below.

Table 4-1- Urban Water Cycle Flows

Flow	Definition
Rainfall	The volume of natural precipitation falling over the Opportunity Areas over an average year.
Roof water	The quantity of rainwater which falls directly on rooftops within the Opportunity Areas. This has been split from storm water due to the differing water quality characteristics.
Stormwater	Runoff from the urban environment generated during rainfall events. This consists predominately of runoff from impervious areas. This flow has been split from roof water above; however, within the current system, both roof water and storm water are combined and enter the drainage system.
Evapotranspiration	Water which is returned to the atmosphere through the processes of evaporation and transpiration of vegetation, on permeable surfaces.
Infiltration	The proportion of rainwater which infiltrates through the soil, entering the groundwater table.
Potable water	High quality water supplied for uses within the home, including water used for drinking and use in the kitchen and bathroom. Within this analysis, potable water has been assumed as necessary for all household uses except toilet flushing.
Non-Potable Water	Water which is utilised for low-contact uses including irrigation and toilet flushing. In general, this water is not required to be of the same quality as that used for potable uses. Under the current scenario in the Opportunity Areas, water for all uses is supplied from the centralised, potable system. In some circumstances, water for use in the laundry may also be supplied by non-potable sources; however, this has not been included in the presented analysis at this stage.
Grey Water	Wastewater generated from use in hand basins, baths and showers. Grey water generally excludes water used in toilets, the kitchen or for cleaning use, which has a greater concentration of contaminants.
Black Water	Wastewater generated from toilets, kitchen and laundry use. This has a higher concentration of contaminants than grey water. Under the current scenario both black water and grey water are combined and disposed to the drainage system.

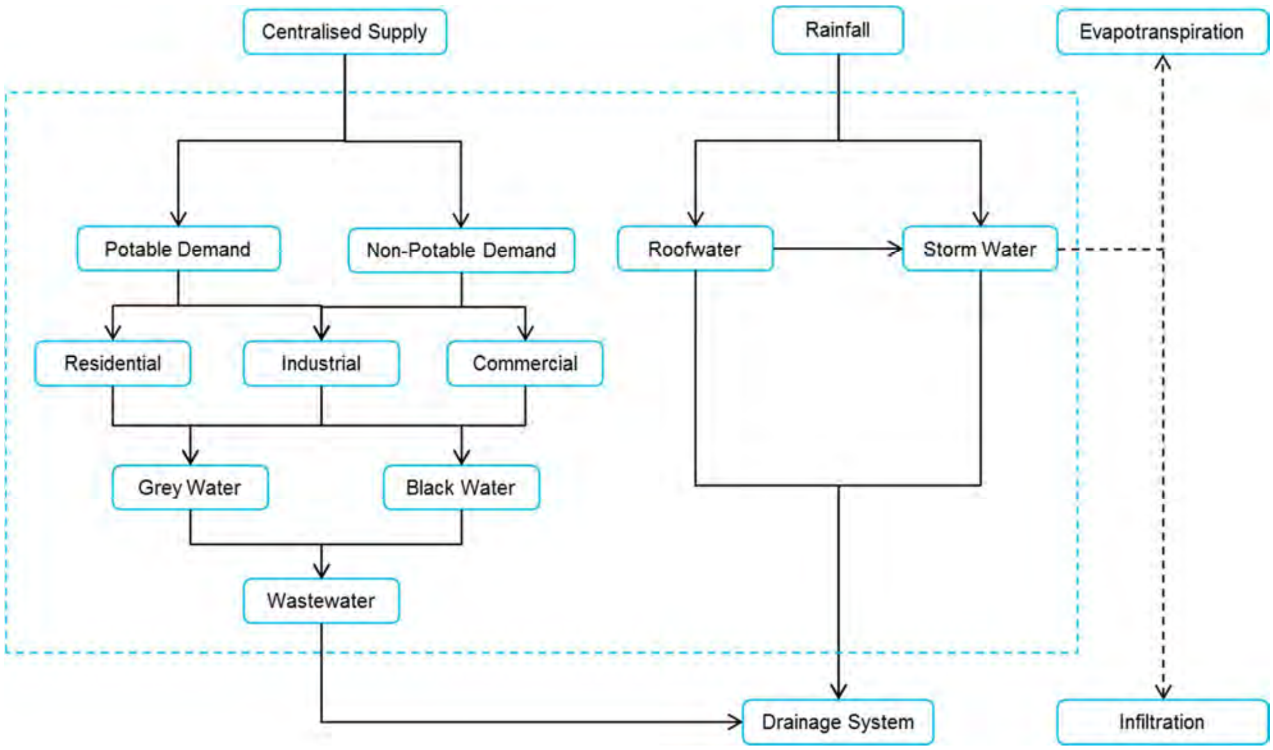


Figure 4-1: Conceptualisation of the pre-development water cycle

4.1.1.4 The objective of the water balance model is to provide a framework for addressing and prioritising water concerns, and highlighting opportunities in terms of alternative supplies and potential mitigation measures.

4.1.1.5 Figure 4-2 below illustrates of how the pre-development water cycle could theoretically be adapted to utilise the water cycle flows within the development to reduce demand and discharge.

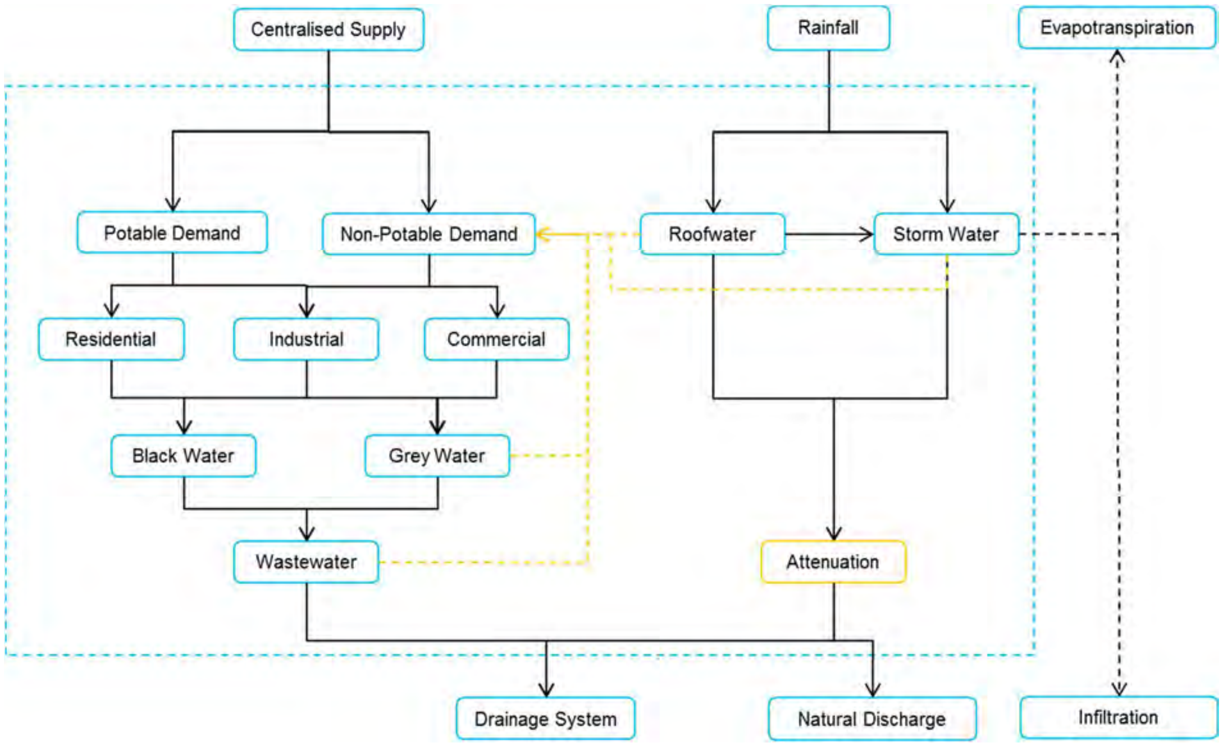


Figure 4-2: Conceptualisation of a post-development water cycle scenario

4.1.2 Water Balance Calculations

4.1.2.1 The water balance model was constructed to calculate the flows for baseline and the post development condition using the best available information, and the outputs are presented in the following section. Key assumptions used in formulating the water balance model are broadly described below.

4.1.2.2 In order to construct the model, Park Royal was divided into 5 separate sub-areas, and Old Oak Common was divided into 8 separate sub-areas. All calculations were undertaken for individual land plots, building up the water balance for each sub-area, which subsequently fed into the overall wider site balance. The sub-area boundaries were developed based on physical infrastructure constraints (such as major transport routes) but which would not necessarily have hydrological catchment splits within them. The defined sub-areas are illustrated in Appendix D and Figure 4-3 below.

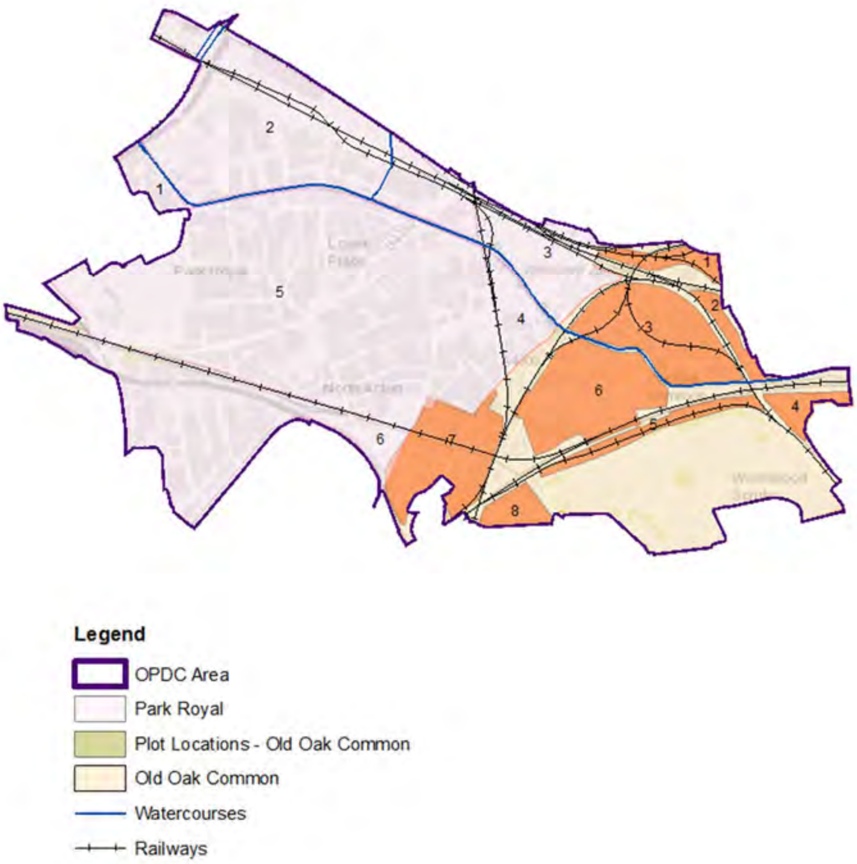


Figure 4-3: Defined sub areas for Old Oak Common (orange) and Park Royal (Purple)

4.1.2.3 Existing and proposed development areas, land use information and occupancy were assumed using GIS layers and masterplan information provided by the OPDC. Rainfall data provided by the Environment Agency was used to generate average monthly rainfall depths; with runoff values estimated using assumptions of the percentage of imperviousity and average hydraulic conveyance for each land use. Water demands and wastewater generation was estimated using usage assumptions based upon the Building Regulations 2010 Part G (2015 Edition) and British Standard BS8524:2001. For both of these methodologies, the total water demand is based on assumptions on the use of sanitary fittings. A range of efficiency scenarios were tested for the existing and new land uses; however, it has been generally assumed that all new development will meet the maximum standards of water efficiency as specified in the London Plan.

4.1.2.4 Estimates for evapotranspiration were obtained using the Penman-Monteith method, using monthly climate inputs taken from local Bureau of Meteorology online records. A balancing value for infiltration has also been used to complete the mass balance. These values have not been shown in the figures below, due to the lower relative confidence and importance of these values to the water management strategy. In considering these calculations, it should be noted that the master-planning for this area is still at an early stage, and therefore only limited resolution is currently available regarding the anticipated residential, commercial and industrial developments. Additionally, only limited information on the current water use within these Opportunity Areas could be sourced, particularly for the industrial site uses within Park Royal. Therefore, whilst the model calculations provide a good indication of the relative magnitude of various flows, they are based on several assumptions and simplifications in order to facilitate strategic-level analysis and planning, and should not be regarded as assured volumes. More detailed analysis will be required at a later stage in order to determine the exact volumes, and a detailed design of the required infrastructure will need to be undertaken.

4.1.3 Existing Scenario

4.1.3.1 The overall pre-development annual water balance for the Opportunity Areas is shown in Figure 4-4. Given the highly urbanised nature of the catchment, the majority of rainfall is discharged to the drainage system as urban rainfall runoff (including roof water and storm water). The relatively low density of the industrial land uses across the current site results in a comparatively lower centralised water demand and sewage discharges, as compared to the runoff volumes.

4.1.4 Developed Scenario

4.1.4.1 The anticipated water balance for the developed site is illustrated in Figure 4-5 below. It may be observed that the increase in population, as a result of the proposed high-density development will result in a dramatic increase in the demand for water and subsequent generation of wastewater. There is also an increase in the proportion of urban runoff falling on rooftops. A minor increase in permeable area is also anticipated as a result of the proposed development (associated with community space), which is anticipated to slightly reduce the overall volume of urban runoff.

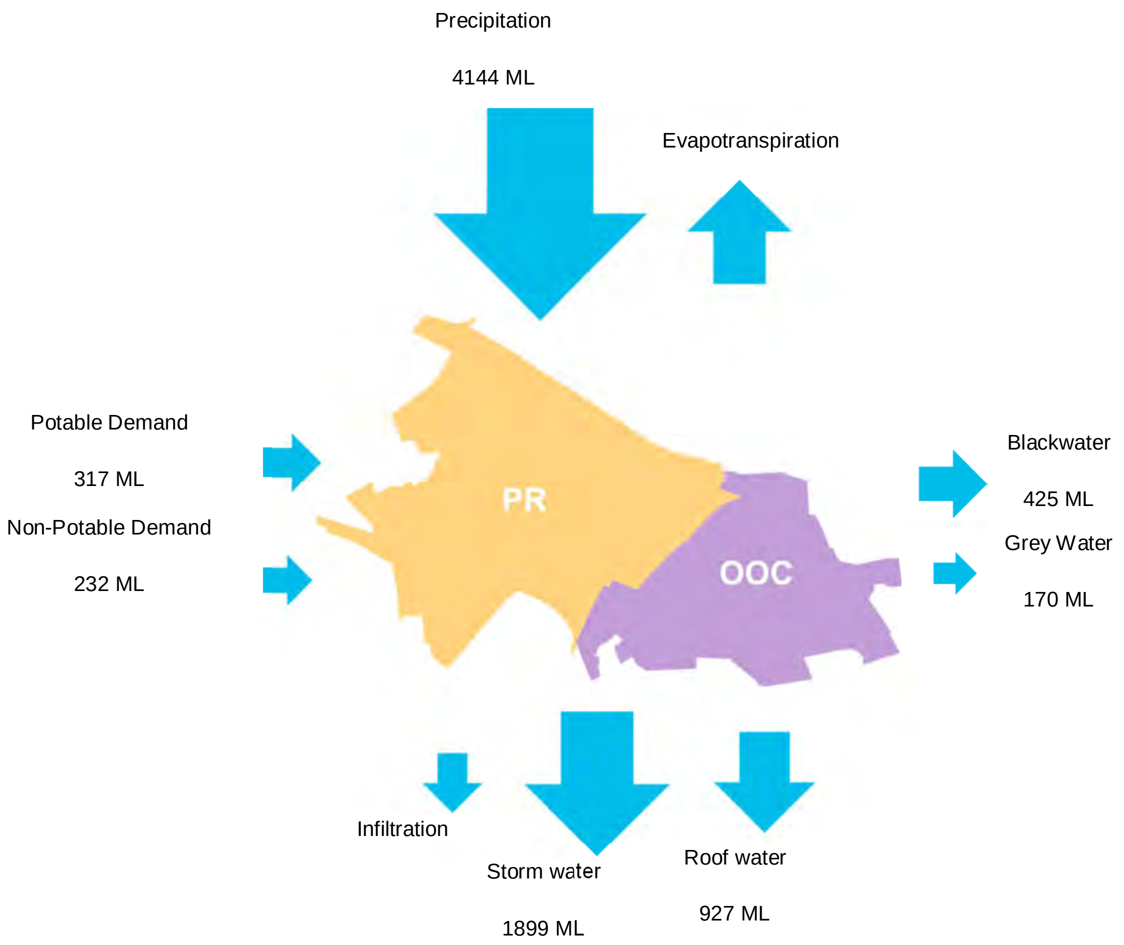


Figure 4-4: Pre-Development annual water balance for the Opportunity Areas

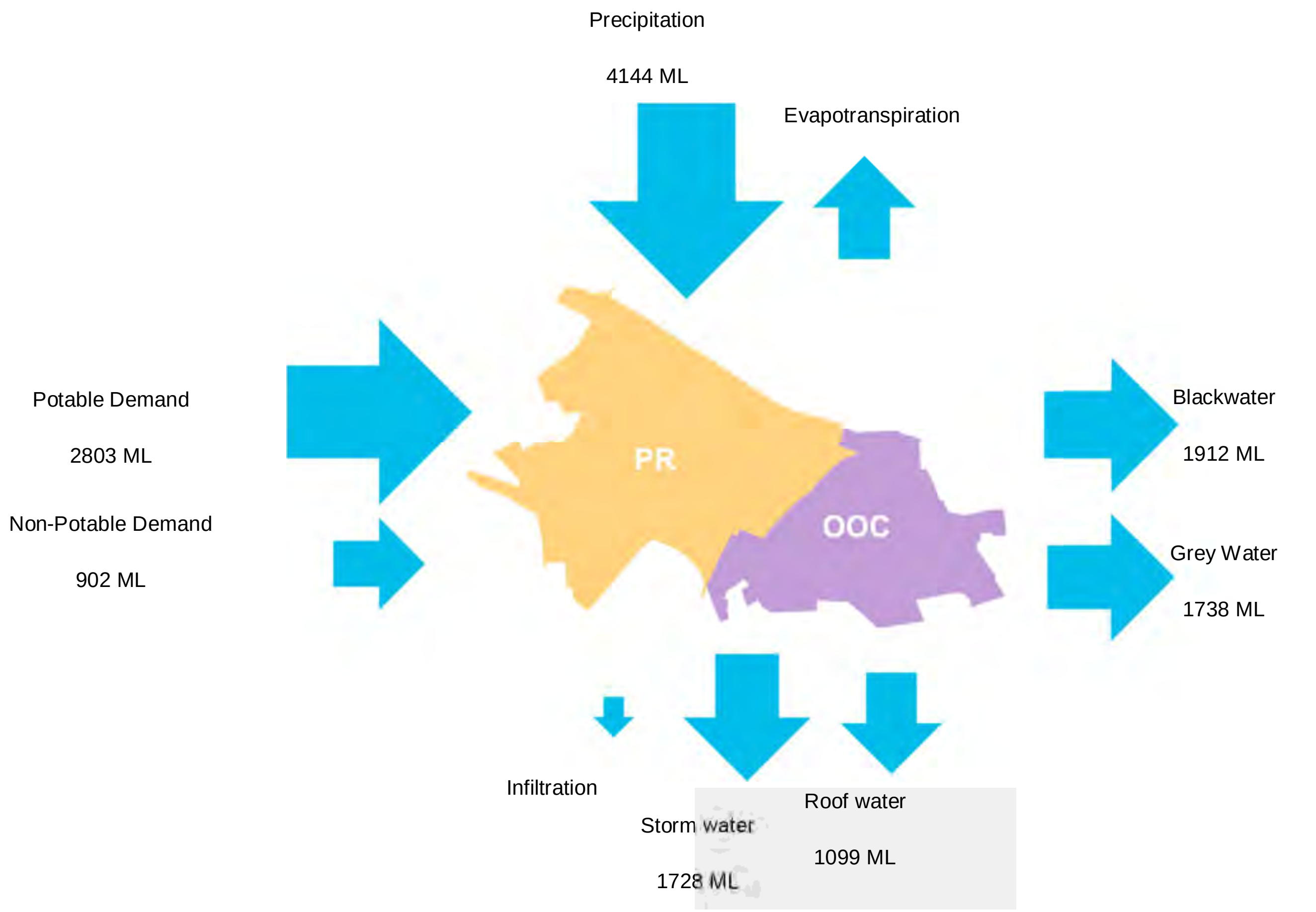


Figure 4-5: Post-Development annual water balance for the Opportunity Areas

4.1.4.2 The magnitude of the anticipated increase in water demand and wastewater generation anticipated from the proposed development is further illustrated in Figure 4-6 below.

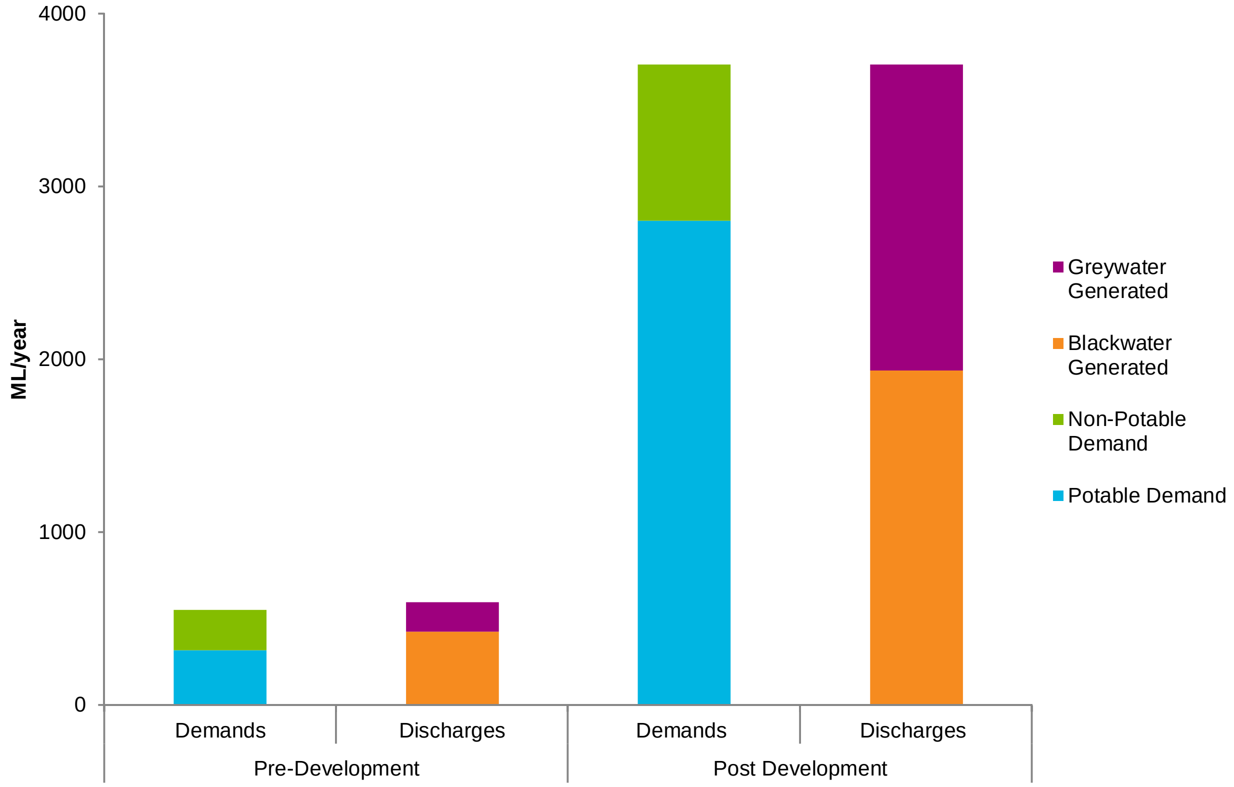


Figure 4-6: Anticipated increase in flow over the Opportunity Areas

4.1.4.3 As these figures illustrate, without intervention, the proposed development of the Opportunity Areas will significantly increase demand on the regional water supply and wastewater assets. The capacity of these systems to cope with increased demand of this magnitude is limited, unless provisions are made to mitigate this impact. However, in considering Figure 4-5, it can be seen that there are several opportunities present to mitigate this impact. Significant streams of water are exiting the system, discharged as waste streams which could be recycled to significantly reduce the overall external demands and discharges.

4.1.5 Spatial distribution of annual flows

4.1.5.1 The water balance demonstrates the overall flows which are anticipated across the whole of the Old Oak Common and Park Royal. However, these flows are not expected to be evenly distributed across each of the areas in this pattern. Figure 4-7 illustrates this split of flows across the two areas. This spatial split presents constraints in holistic management of the water resources across the two areas. In particular, the majority of the high-density regeneration and new housing is expected in Old Oak Common, while the largest surface areas, collecting rainfall runoff, are located in Park Royal.

4.1.5.2 Additionally, the topography and existing water infrastructure influence the split of these flows. Surface water runoff will tend to drain along the natural topographical catchments of the areas towards the local waterways (some of which are incorporated into the sewer system). As a result, surface water flows within Old Oak Common and the eastern extents of Park Royal, including the HS2 construction sites, will tend to flow towards the south east and Wormwood Scrubs. The majority of Park Royal will tend to drain towards the River Brent.

4.1.5.3 The existing drainage infrastructure also artificially influences the split of these flows as shown. The vast majority of collected surface water and sewage collected across the two areas is transported to the Counter’s Creek catchment, except the most western extents of Park Royal.

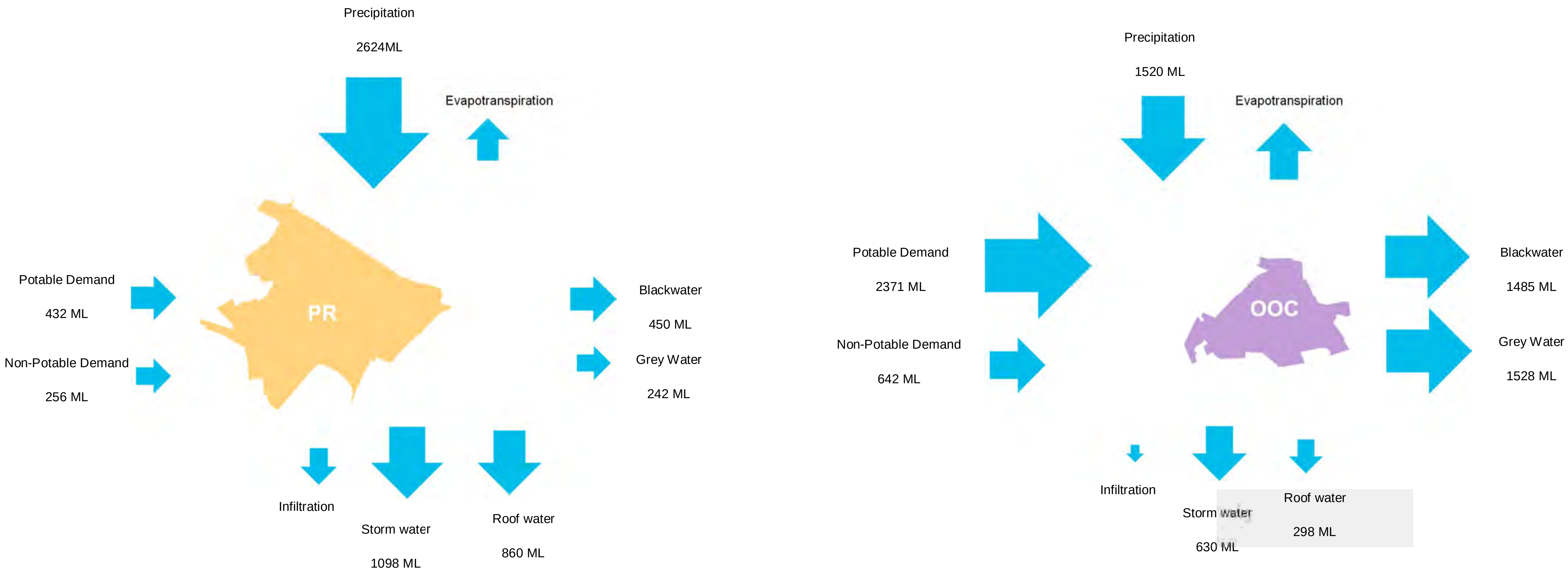


Figure 4-7 - Post-Development annual water balance for the Opportunity Areas

4.2 Peak Instantaneous Water Flows

4.2.1.1 The distribution of the flows as described in the water balance are, in reality not uniform, fluctuating significantly across different days and seasons. Variability in rainfall intensity and subsequent runoff rates of surface water during heavy rainfall events is a key feature determining capacity in the sewer system. In addition, peak wastewater flows from site occupation is also a key factor for sewer capacity in dry weather conditions.

4.2.2 Water Supply and Wastewater Generation

4.2.2.1 Demand for water varies seasonally with the weather. In hot, dry weather, customer usage increases as more water is used for outdoor uses including garden watering; while in cold weather leakage may rise due to an increased number of burst pipes..

4.2.2.2 Water demand also varies diurnally through the day, with the greatest demands occurring in the morning and evening, before and after the average working day. Thames Water modelling standards indicate that a peak factor of 2.12 times the average flow should be used to represent peak residential sewage flows, and 3 used for commercial flows (excluding infiltration)[4]. Considering the water balance presented above, the estimated pre and post-development peak sewage flow for each area is indicated in Table 4-2.

Table 4-2- Estimated Increase in peak instantaneous sewer discharge (excluding infiltration)

	Estimated Peak Sewer Discharges	
	Pre-Development	Post-Development
Old Oak Common	14 L/s	217 L/s
Park Royal	43 L/s	60 L/s

4.2.3 Rainfall, Runoff and Flooding

4.2.3.1 Rainfall varies seasonally across the year. On average, the majority falls in the autumn months of October and November and the driest month is February, as shown in Figure 4-8. Although, there is a large variance in the annual rainfall totals in London as well as the distribution of that rainfall across the year. The rainfall occurring within a week or day also varies significantly, depending on the number and intensity of storm events. The volume of rainfall that falls in a short space of time, during significant storm events has a significant impact on local drainage systems.

[4] Peaking factors based on diurnal profile in *CIRIA 177: Dry Weather Flows in Sewers (1998)*

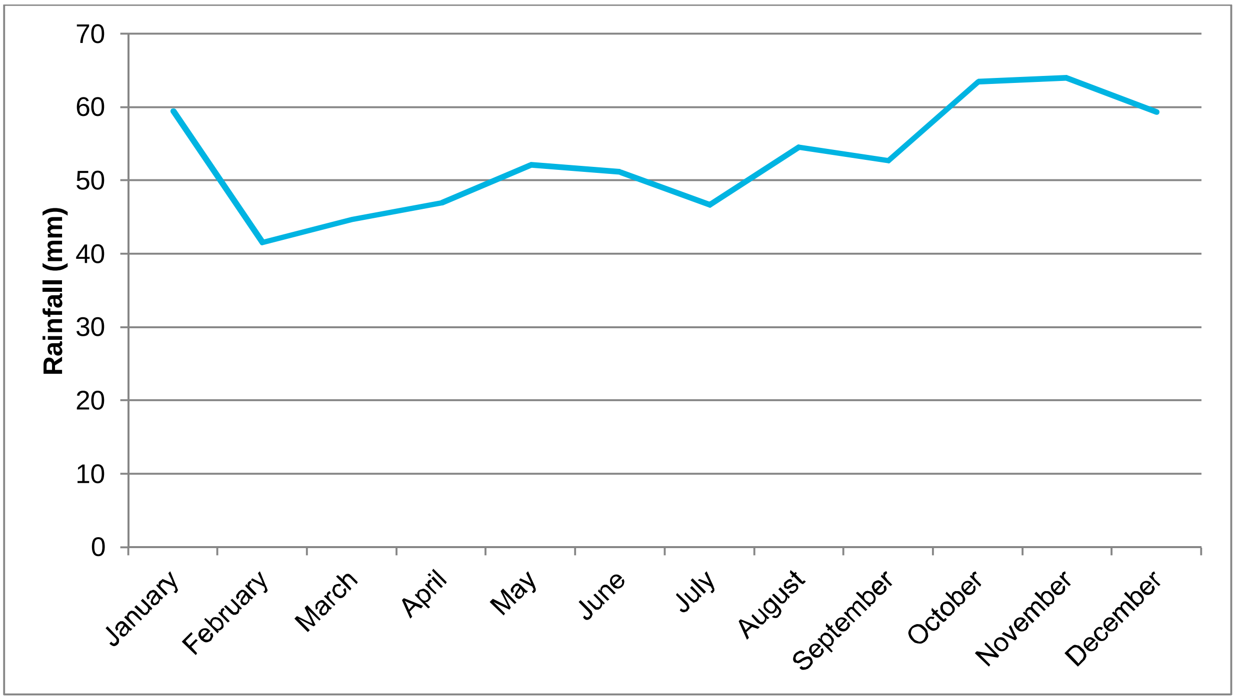


Figure 4-8: London average monthly rainfall (mm), as recorded between 1960 and 2015

4.2.3.2 Catchment urbanisation increases the impact of high intensity storm events, through removal of the natural processes of infiltration, interception and evapotranspiration on naturally vegetated surfaces. The resultant increase in the volume and speed of runoff causes significant and rapid loading to be imposed on drainage systems during storm events. Current Thames Water standards provide for a design drainage capacity of 1 in 30 years. However, drainage systems across London are of varying age, with capacity for a highly variable range of storm events. In events exceeding the design capacity, the system may be susceptible to surcharge and flooding. The majority of the Old Oak and Park Royal regions discharge to the Counters Creek Catchment, which is a combined sewer system. This system is known to experience surface water and combined sewer flooding during storm events, with drainage systems known to surcharge during storms as low as a 1 in 2 year event in some cases.

4.2.3.3 As such, a key aspect of the water management strategy for the Opportunity Areas will be in reducing the surface water flows entering the combined sewer system, and providing attenuation to reduce the peak flow rate at which this discharges. This discharge of surface water runoff must be decreased to a level to offset the large increase in peak foul flows and hence allow the scale of development proposed to be achieved. Currently, the minimum anticipated requirement is for developments to reduce site runoff to Greenfield rates. This is the rate at which runoff would naturally discharge from an undeveloped, highly permeable catchment. Currently, the proposed development area is predominately urbanised, with very little green space (except Wormwood Scrubs), which means that this will be a significant challenge. Increasing green, permeable areas within the catchment, and providing attenuation storage and SuDS features will assist in achieving this.

4.2.3.4 Estimated pre-development (brownfield) and Greenfield runoff volumes for the 1 in 20 year storm event are summarised in Table 4-3 below[5]. This is understood to be a critical return period for consideration of current sewer capacity in this region.

Table 4-3 - Estimated pre-development and Greenfield Runoff Rates for the 1 in 20 year rainfall event

	Estimated Runoff	
	Pre-Development	Greenfield
Old Oak Common	42,130 L/s	3,224 L/s
Park Royal	11,858 L/s	907 L/s

[5] Due to the size of the Opportunity Areas, the exact Greenfield runoff rate and required attenuation should be confirmed for individual development plots during planning and design.

4.2.3.5 Considering these flows in comparison to the peak sewage flows described in in Table 4-2, it may be observed that the reduction in instantaneous surface water flow entering the combined drainage system during storm events (through achieving Greenfield runoff rates), will be substantially in excess of the anticipated increase in peak sewage flows. Therefore, effectively managing the surface water discharge to achieve Greenfield rates will be essential to creating capacity within the sewer system.

4.2.3.6 In order to establish the attenuation volume required across the Opportunity Areas, anticipated runoff rates for the critical 1 in 100 year climate change event have been calculated, and required volumes determined. The volumes required for each sub-area (as illustrated in Figure 4-3) are summarised in Table 4-4 and Table 4-5 below.

Table 4-4- Attenuation storages required to achieve Greenfield Runoff Rates for each sub-area in Old Oak Common.

Old Oak Common Sub- Area	Attenuation Storage Required (m^3)
1	1,937
2	1,552
3	7,897
4	1,839
5	2,627
6	9,610
7	6,139
8	1,851
Total	**33,452**

Table 4-5- Attenuation storages required to achieve Greenfield Runoff Rates for each sub-area in Park Royal.

Park Royal Sub- Area	Attenuation Storage Required (m^3)
1	4,319
2	56,713
3	15,752
4	6,664
5	113,073
6	40,417
Total	**236,937**

5 Water Management Measures

5.1.1.1 This section highlights a number of water management measures that may be implemented to mitigate the anticipated issues associated with the proposed development. The delivery (and performance) of these measures will vary across the Opportunity Areas, due to the different challenges and water use characteristics of each area. Within Old Oak Common and new build areas of Park Royal (predominately associated with the HS2 construction sites); a range of new infrastructure will be required, providing significant opportunities for the simultaneous delivery of efficient, decentralised water management and sustainable drainage systems as a part of the development. However, to achieve the objectives across the remaining areas of Park Royal, there would need to be a retrofit or incremental replacement of systems as the majority of land uses would remain. This area is also constrained by the existing landscape, which will have significant cost and feasibility implications. Due to these factors, the applicability of various measures has been considered separately for Old Oak Common and existing and new build areas of Park Royal.

5.1.1.2 Each of the described measures has been scoped using an assumed technology in each of these areas, and their performance assessed across the key project objectives, and a range of wider deliverability and sustainability criteria. These criteria have been discussed and refined in conjunction with key stakeholders, in order to reflect the overall priorities for sustainable water management within the development, as broadly described below. In addition to assumed technology, a range of potential innovations for some measures has been included to set initial detail on how each of the measures could be implemented in the most sustainable and efficient way.

5.2 Performance Criteria

5.2.1.1 Key Water Management Objectives

5.2.1.2 Without mitigation, there are a number of water management issues foreseeable as a result of the proposed development. Arising from these, the core objectives to be delivered through the integrated water management strategy are:

- *Providing attenuation and sustainable drainage features to achieve Greenfield quality and quantity of runoff* - Providing sufficient attenuation to retain and reduce peak storm flows to the Greenfield runoff rate will reduce downstream flood risk, and provide additional sewer capacity to handle the significant increase in foul flows arising from the development during high intensity rainfall events. The incorporation of SuDS features will additionally provide substantial water quality benefit.
- *Minimising demand on the centralised potable water supply as far as possible* - increasing water efficiency, managing demand and implementing fit for purpose water recycling will contribute to mitigating the impact of the development on the critical supply levels across London.
- *Achieving a neutral discharge volume of combined wastewater-* Both of the objectives described above will also contribute to minimising the volume of wastewater and surface water discharged, mitigating the impact of the development on the already limited capacity of the existing drainage infrastructure.

5.2.1.3 In assessing each measure against these objectives, the following scoring brackets have been used (Table 5-1):

Table 5-1: Scoring brackets used to assess each water management measure.

	No Benefit	Low	Medium	High
Potential Demand Reduction	No reduction	Anticipated 0-9% reduction	Anticipated 10-19% reduction	Anticipated 20+% reduction
Potential Volumetric Discharge Reduction	No reduction	Anticipated 0-9% reduction	Anticipated 10-19% reduction	Anticipated 20+% reduction
Potential Attenuation for Peak Storm Flow Reduction	No contribution	Anticipated 0-9% contribution to required attenuation	Anticipated 10-19% contribution to required attenuation volume required	Anticipated 20+% contribution to required attenuation volume required

5.2.1.4 Deliverability Considerations

5.2.1.5 The feasibility of each measure relates the overall spatial and financial viability, and the anticipated ease of delivery. This has been considered in term of the below aspects:

- *Capital cost* - Embedded within this criterion are feasibility considerations associated with infrastructure requirements, construction cost and buildability constraints associated with installation in new build and retrofit environments.
- *Operational and maintenance requirements* - Many of the options presented will have continuing operational, maintenance or monitoring requirements, with an associated ongoing cost implication, and potential challenges in determining relevant responsibility and ownership.
- *Effective spatial requirements* - Spatial requirements for many of the proposed options will present a particular constraint to the feasibility of delivery, due to the required high density nature of the proposed development.
- *Regulatory challenges and public acceptance* - Existing regulation and legislation in the water management area is complex and fragmented, with a lack of a comprehensive regulatory framework, which may present operational and commercial risks. Additionally, the social effects of innovative solutions to sustainable water management need to be carefully considered.
- *Flexibility and scalability of delivery* - The flexibility and scalability of measures relates to the ability to react to the phasing of development delivery and the extent to which significant upfront costs are incurred, or whether these may be spread over the re-development delivery, and how these can be clearly distributed amongst delivery partners.

5.2.1.6 To assess these deliverability aspects, each of the presented measures has been assessed in terms of the estimated capital cost. This has been presented as a proportion of the estimated capital cost of the overall development (or existing area), and assigned a cost bracket, as shown in Table 5-2 below.

Table 5-2 - Scoring brackets used to assess the capital cost of each water management measure

	Low	Medium	High	Very High
Indicative Cost	0-1% of estimated capital construction cost of area	1-2% of estimated construction cost of area.	2-3% of estimated construction cost of area	3+% of estimated construction cost of area

5.2.1.7 The remaining deliverability aspects have been assessed comparatively on a qualitative basis, using quantitative indicators where possible. These have been assigned a score of None, Low, Medium or High.

5.2.1.8 Sustainability Considerations

5.2.1.9 Sustainability considerations are those related to broader long term sustainability and climate resilience of the presented measures, as well as the extent to which they will deliver added benefits to the local community. This has been considered in terms of the following aspects:

- *Carbon intensity* - Each of the measures has an impact in terms of embedded carbon and ongoing operational energy, associated with water supply, pumping and wastewater treatment. Green infrastructure can additionally also contribute to removing greenhouse gasses from the atmosphere and sequestering them over the long term. Shading impacts can also result in reduced use of mechanical cooling in the summertime and reduction in demand for water.
- *Blue-green space provided* - Through high design and maintenance standards, the delivery of blue and green infrastructure can enhance the urban environment for the benefit of communities and biodiversity. Particular benefit may be related to the following indicators:
    - *Provision of habitat and biodiversity* - when sufficiently planned, the delivery of diverse, high quality green spaces can provide valuable habitat to a range of flora and fauna, including birds and invertebrates, while contributing to green corridors, allowing the movement of species through urbanised spaces.
    - *Recreation and community* - provision of space for recreation and contribution to community health, wellbeing and social cohesion. Water features can create a sense of place.
    - *Microclimate adaptation* - Reducing the impact of the urban heat island effect by providing shading to protect against radiations, reducing local temperatures through evapotranspiration and reducing heat absorbed and then released by surfaces.
    - *Public realm* - street greening and the delivery of effectively landscaped open spaces can substantially improve the attractiveness and amenity of neighbourhoods.
- *Climate Resilience* - Each of the various options presented differ as in the extent to which the option is resilient in itself to the effects of climate change. Options which are dependent on rainfall to meet water supply needs have a potentially lower resilience to climate change. More generally, increasing the diversity of available water supply options can also contribute to increasing the overall resilience of the system to climate change and other future disturbance, through increased flexibility and adaptability of supply options.
- *Surface water quality* - Many SuDS components, particularly those incorporating natural, vegetative or bio-retention processes, provide opportunities to improve water quality (meeting helping to meet Water Framework Directive targets) and by treating diffuse water pollution through mechanisms including sedimentation, filtration and biological degradation. These components can also reduce the amount of surface water reaching end watercourses (reducing erosion and pollution), and entering sewers, adding to subsequent treatment requirements and possible CSO spills

5.2.1.10 These items have similarly been assigned a comparative qualitative score, based on the characteristics of the presented measure, using quantitative indicators where possible. These have been assigned a score of None, Low, Medium or High.

5.3 Demand Management

5.3.1.1 Demand management strategies are generally the first priority for sustainable water management and should be considered wherever possible. Demand management conserves potable water supplies and reduces the generation of wastewater. It is assumed in new build areas that development will be delivered to the latest guidance issued in the London Plan, promoting the highest current industry standards with respect to water efficiency, through the incorporation of water saving measures and equipment.

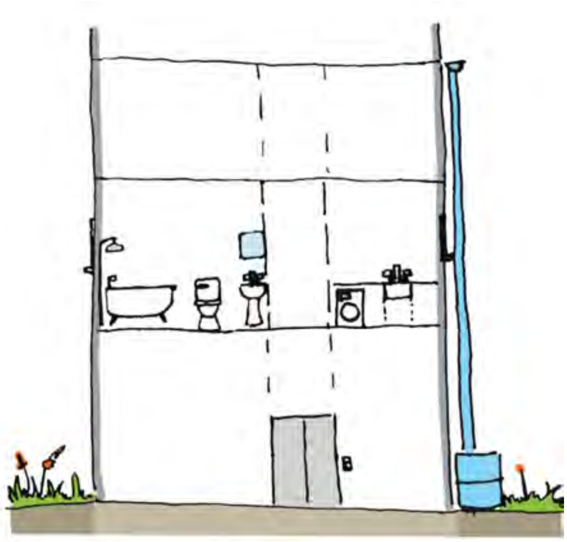


Figure 15 - Water efficient fittings

5.3.1.2 A range of new centralised water supply infrastructure will be required in New Build Areas, presenting an opportunity for the installation of smart network technologies to optimise operation. Such systems and technologies enable remote, real time monitoring of water usage, allowing rapid targeting of leakage, operation issues and system inefficiencies. Additionally, customers can be provided with the information and tools they need to make informed choices about their behaviours and water usage patterns. Detailed monitoring of water quality parameters will also be invaluable in assessing the performance and future potential of water recycling systems.

5.3.1.3 Within retained existing areas of Park Royal, there are likely to be significant water savings to be realised through targeted water efficiency retrofits, process improvements and installation of modern technologies. Given the expected age of many of the properties within Park Royal, it is likely that modern processes and new technologies may be able to result in substantial reductions at many locations.

5.3.1.4 Community education, engagement and incentive schemes can also be utilised to improve consumer behaviours and encourage the uptake of water conservation practices and technologies. A downside of specifying water efficient fixtures and fittings is that they can be replaced for less efficient versions once the development is sold on and as such is not a guaranteed reduction in potable water demand.

5.3.1.5 Innovation in Demand Management

5.3.1.6 Driven by requirements such as those from BREEAM, water efficient fixtures and fittings are now largely commonplace, such as 6/3.5 dual flush toilets and aerating showers that retain the feeling of power by mixing pressured air with the water flow. The challenge to retain performance levels however remains, and at present although it is technically possible to find fixtures and fittings to deliver a reduction in water use to under 80lpd, the delivery of these additional efficiency savings from around the current 105-120lpd risks the ability to maintain user satisfaction. Damaging user satisfaction in turn runs the risk that the water saving fixtures and fittings will be replaced by less efficient alternatives, undermining these key measures to reducing potable water demand.

5.3.1.7 *Duravit Rimless* – One of the main performance challenges of low flow toilets is to maintain hygienic cleaning the power of the flush with limited water. To resolve this, the focus has been to increase the velocity of horizontal flows as well the traditional vertical flush. The Duravit Rimless is an example of a new range of toilets that create a cyclonic flow in order to clean the bowl.

5.3.1.8 Advances in sensing and monitoring are allowing more targeted and controlled use of water, as well as raising awareness that supports behavioural responses that help reduce water demand.

5.3.1.9 *Smart Meters* – Smart metering systems allow consumers to monitor water usage in real time, giving greater control and transparency over water bills. Like a number of water companies, Thames Water have embarked on a programme of installing water meters, and one would be expected that smart water meters would be installed in new properties, delivering on average around 12% saving. Smart water metering will also have benefits in detecting leaks, as above normal usage can be easily identified and flagged. The real innovation will come in combining water metering with other smart home and offices systems to give complete utility control through one device.

5.3.1.10 *Network Sensing* – As with home/office water management, there are a number of emerging sensing technologies to reduce network losses and improve the efficiency of water networks. These include leak detection monitors which area able to pinpoint more accurately the damaged section of pipework by monitoring the pressure and vibrations caused from flowing water. Potable water distribution and transmission networks often operate at needlessly elevated pressures. As such, water companies are looking to optimise network pressures by reducing pressure when demand is low to save on pumping energy. I2O water has developed a system whereby District Metered Area valves are automatically controlled based on how the pressure at key locations in the network compares with a pre-determined minimum threshold pressure. Similarly variable frequency drives are becoming a mainstream approach to managing localised fluctuations in pumping demand to be more energy efficient.

5.3.1.11 *Micro-climate controlled irrigation* – Different plants require different growing conditions, and micro-climate can vary considerably across sites. Smart irrigation systems combine soil moisture and localised wind monitoring, along with an understanding of the plants optimum hydration, to deliver tailored irrigation requirements to different parts of the same site.

		Park Royal - Retained	Park Royal - New Build	Old Oak Common
Characteristics	**Assumed Technology**	Retrofit of water efficient devices within existing industrial properties to meet the current efficiency standards, as specified in the building regulations.	All new build developments constructed to the water efficiency requirements specified in the London Plan.	All new build developments constructed to the water efficiency requirements specified in the London Plan.
Characteristics	**Applicable Scale**	Building scale		
Core Objectives	**Potential Potable Water Savings**	**HIGH -** Up to 27% reduction (122 ML/year)	**MEDIUM** - Up to 11% reduction (28 ML/year)	**MEDIUM -** Up to 14% reduction (408 ML/year)
Core Objectives	**Potential Discharge Reduction**	**LOW** - 6% reduction of total drainage discharge (122 ML/year)	**MEDIUM** - 7% reduction of total drainage discharge (28 ML/year)	**MEDIUM** - 11% reduction of total drainage discharge (408 ML/year)
Core Objectives	**Potential Attenuation Contribution**	**NONE**		
Feasibility	**Indicative Cost**	**MEDIUM** - Estimated 1-2% of capital construction cost (£26,500,000)	**LOW** - Estimated 0-1% of capital construction cost (£2,000,000)	**LOW** - Estimated 0-1% of capital construction cost (£24,000,000)
Feasibility	**Spatial requirements**	**NONE-** Minimal requirements above standard fittings		
Feasibility	**Maintenance Requirements**	**LOW -** Minimal requirements above standard fittings		
Feasibility	**Regulatory and Public Acceptability**	**HIGH -** Supported by current planning policy and regulation. Potential for public acceptability uptake to decrease if user satisfaction diminishes,		
Feasibility	**Flexibility and scalability**	**HIGH -** Ability for gradual implementation and retrofit, harnessing latest available technologies.		
Sustainability	**Carbon intensity**	**LOW -** Technologies can also result in reduced energy consumption, through reducing the energy consumption of pumping and hot water systems.		
Sustainability	**Blue-green space provided**	**NONE**		
Sustainability	**Climate Resilience**	**MEDIUM -** Reduced consumption resulting in reduced strain on existing resources.		
Sustainability	**Surface water quality**	**LOW -** Marginal benefit through reduced flows to sewer, with reduced associated impact on downstream receiving waterbodies.		

5.4 Green Roofs

5.4.1.1 Green roofs consist of a planted soil layer, constructed on the roof of a building to create a living surface. The vegetated substrate is generally built on top of a drainage layer. Following rainfall, water is stored in the soil layer and absorbed by vegetation. Green roofs may be designed to be constructed to be accessible, and landscaped to provide biodiversity and community benefit. In many cases, it may be beneficial to combine vegetated roofs with roofwater collection storages to create blue-green roofs, where the stored water can be used to provide an additional balancing irrigation supply for vegetation. Green roofs may be constructed on new buildings, or retrofitted onto existing surfaces, although, in some cases there will be restrictions on the ability to retrofit due to inadequate structural capacity or overly sloping surfaces, and are likely to be more expensive.

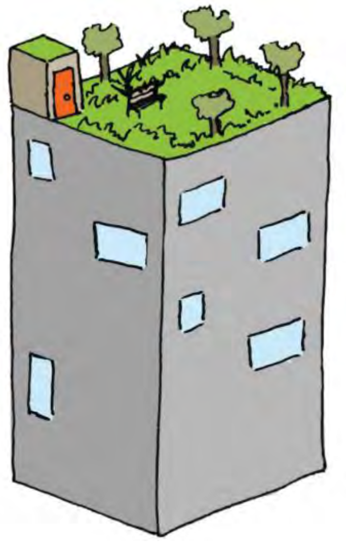


Figure 16 - Intensive green roof

5.4.1.2 The construction of Green Roofs will result in a reduction of runoff occurring from roof surfaces, through adsorption, and evapotranspiration by the rooftop vegetation. The reduction in impervious surface will also provide benefits in reducing the speed of runoff and providing water quality benefits through filtration and bio-retention. Green Roofs also have the potential to provide a range of wider benefits, including provision of habitat for biodiversity, improved air quality, recreational and amenity benefits and amelioration of the urban heat effect. Living walls and green facades may also be suitable for installation and provide similar functions and benefits as green roofs.

5.4.1.3 Innovation in Green Roofs

5.4.1.4 There have been a number of advances in green roof technologies, particularly in the development of easier to assemble modular kits, irrigation systems and protective membranes. There have also been advances in planting application. As with surface SuDS, plant selection and the substrate composition that can have a number of water quality benefits in addition to reducing run-off rates. Roof-top wetlands have even been used to treat rain and grey water for reuse in the buildings on which they are situated.

		Park Royal - Retained	Park Royal - New Build	Old Oak Common
Characteristics	**Assumed Technology**	Retrofit of lightweight, extensive green roofs on existing buildings.	Intensive, landscaped green roofs installed on all new buildings.	Intensive, landscaped green roofs installed on all new buildings.
	Applicable Scale	Building scale		
Core Objectives	**Potential Potable Water Savings**	**NONE**		
	Potential Discharge Reduction	**MEDIUM -** Up to 10% reduction of total drainage discharge. (223 ML/year) through greater absorption and evapotranspiration.	**LOW -** Up to 9% reduction of total drainage discharge. (35 ML/year) through greater absorption and evapotranspiration.	**LOW -** Up to 4% reduction of total drainage discharge (167 ML/year) through greater absorption and evapotranspiration.
	Potential Attenuation Contribution	**LOW -** Estimated water storage capacity of approximately 1% of required attenuation volume.	**LOW -** Estimated water storage capacity of approximately 6% of required attenuation volume.	**HIGH -** Estimated water storage capacity of approximately 25% of required attenuation volume.
Feasibility	**Indicative Cost**	**VERY HIGH** - Estimated 3+% of capital construction cost (£175,000,000)	**HIGH -** Estimated 1-2% of capital construction cost (£16,000,000)	**LOW -** Estimated 0-1% of capital construction cost (£33,000,000)
	Spatial requirements	**LOW -** No additional land take.		
	Maintenance Requirements	**LOW -** Irrigation required during establishment of vegetation, ongoing inspection and monitoring of vegetation cover, removal of litter or debris.		
	Regulatory and Public Acceptability	**HIGH -** Supported by current planning policy and potential to provide recreational and amenity benefit		
	Flexibility and scalability	**HIGH -** Ability for gradual implementation as development progresses. Limitations for retrofit on some existing buildings, due to inadequate structural composition or overly sloping surfaces.		
Sustainability	**Carbon intensity**	**LOW -** Potential for carbon sequestration and building insulation, with reduced associated energy requirements.		
	Blue-green space provided	**HIGH -** provision of green space, with the potential to provide recreational and amenity benefit, habitat for biodiversity, improved air and water quality and microclimate benefits.		
	Climate Resilience	**MEDIUM -** Provision of attenuation and vegetation to assist in mitigating the impacts of climate change on drainage systems. Delivery of drought tolerant species is recommended.		
	Surface water quality	**HIGH -** Vegetated system reducing the quantity and the speed of runoff and providing water quality benefits through filtration and bio-retention.		

5.5 Roof Water Recycling

5.5.1.1 Rainwater can be collected from the roof of buildings and stored in underground or over ground tanks for reuse locally. The collected water may be used for garden watering or indoor non-potable uses, such as toilet flushing or hot water and laundry uses. As such, roof water collection contributes to a reduced discharge of urban runoff to the combined and surface water sewer systems and a reduction in potable water supply volume. Due to the reduced exposure to contaminants, treatment infrastructure is often lower than for other types of water; however, disinfection is likely to be required if the water is to be used for higher contact uses including hot water systems, laundry uses or spray applications, and particularly if water is likely to be mixed with centralised potable supplies.

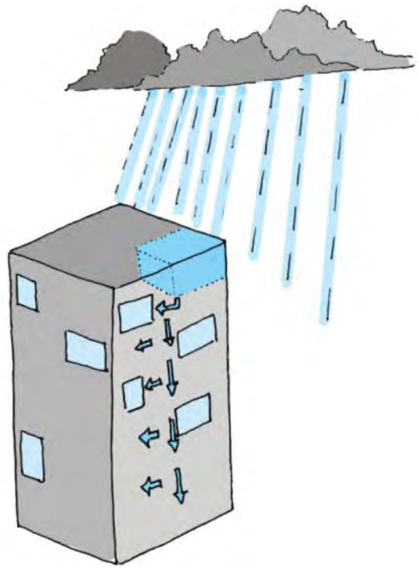


Figure 17 - Plot scale roofwater harvesting

5.5.1.2 Storage volumes for rainwater harvesting are likely to be significant, due to the highly variable nature of the inflow. A key constraint within the Opportunity Areas is the misalignment of demand and catchment availability. Within Old Oak common, the limited rooftop catchments will not provide sufficient flows to meet the non-potable demand within the high density development. If utilised, this would additionally need to be mixed with centralised supplies, with stringent controls necessary to mitigate any risk of cross-contamination. Conversely, significant supply is present in Park Royal due to large rooftop catchments; however, retrofit of dedicated non-potable internal distribution pipework is unlikely to be feasible, limiting recycling to outdoor irrigation, wash-down use, or for specific industrial processes not requiring potable quality water. Transferring water between the catchments would require complex pipework retrofits, which may provide only limited benefit over other area scale non-potable recycling options.

5.5.1.3 Potable re-use of rainwater is also possible, and may present an opportunity for water recycling in the short term, due to the high raw water quality. Allowance for potable augmentation would mean that harvested water could be directly reused, avoiding the challenges of separate non-potable pipework. Stringent water quality control and long-term monitoring and validation would be recommended to mitigate any operational risks.

5.5.1.4 Innovation in Rainwater Harvesting

5.5.1.5 *Gravity fed rainwater harvesting* – The potential for rainwater reuse is perhaps greatest in retrofitting buildings with large roof areas such as within Park Royal. Most rain water harvesting systems collect water at the base of the down pipe for storage underground. This however requires energy to pump the rain water back to where it is to be used; often several floors up. David Bultler from the University of Exeter is one of a number of advocates developing approaches to gravity fed rain water harvesting systems that hold water in the roof space to build up a head of pressure so that pumping becomes redundant.

5.5.1.6 *Aqua-Storm Control* – Large buildings generally require large attenuation tanks to manage storm water. Variation in storm volume and frequency means that this is not viable for reuse. Supplementing this rain water with grey water means that a more reliable non-potable supply can be maintained, however to ensure there is sufficient storm volume reserved in these passive systems, an oversized or dual tank is required, increasing the capital installation costs. Aqua-lity's Aqua-Storm Control systems provides an active solution by using real time weather data to predict future rainfall events. This means that grey water stored for reuse can be slowly released ahead of the storm to provide capacity for the rain water whilst retaining sufficient non-potable water supply all within in a standard sized tank.

		Park Royal - Retained	Park Royal - New Build	Old Oak Common
Characteristics	**Assumed Technology**	Retrofit of roof water harvesting systems on all existing buildings in Park Royal, with water available for outdoor or specific process re-use.	Localised roof water harvesting systems on all new buildings, including collection, filtration, UV disinfection, pumping and non-potable reticulation.	Localised roof water harvesting systems on all new buildings, including collection, filtration, UV disinfection, pumping and non-potable reticulation.
	Applicable Scale	Likely to be most feasible at a building scale or a communal (development) scale.		
Core Objectives	**Potential Potable Water Savings**	**UNKNOWN** - Sufficient available supply to offset non-potable demand (42% 197 ML/year). However, pipework constraints will limit the extent to which this may be utilised.	**HIGH** - Up to 27% reduction in demand (62 ML/year)	**LOW** - Up to 8% reduction in demand (238 ML/year)
	Potential Discharge Reduction	**LOW -** Up to 9% reduction of total drainage discharge (197 ML/year)	**MEDIUM -** Up to 16% reduction of total drainage discharge (63 ML/year)	**LOW -** Up to 6% reduction of total drainage discharge (238 ML/year)
	Potential Storage Contribution	**MEDIUM -** Water storage will be provided; however, it is unlikely that this capacity will be all available to provide storage during storm events.	**MEDIUM -** Water storage will be provided; however, unlikely that this capacity will be all available to provide storage during storm events.	**HIGH -** Water storage will be provided; however, unlikely that this capacity will be all available to provide attenuation storage during storm events.
Feasibility	**Indicative Cost**	**VERY HIGH** - Estimated 3+% of capital construction cost (£72,000,000)	**HIGH -** Estimated 2-3% of capital construction cost (£13,500,000)	**MEDIUM -** Estimated 1-2% of capital construction cost (£58,000,000)
	Spatial requirements	**LOW -** Spatial requirements for water storage, to manage variability in rainfall; however, below ground or rooftop storage can minimise additional land take.		
	Maintenance Requirements	**MEDIUM -** Ongoing inspection and cleaning of collection systems, filters, valves and pumps. Requirement for ongoing treatment and pumping.		
	Regulatory and Public Acceptability	**MEDIUM** - Perceived as a relatively high quality water source; however, potential for regulatory barriers, particularly if harvested supplies are required to be mixed with centralised supply to meet non-potable demand.		
	Flexibility and scalability	**HIGH -** Ability for gradual implementation as development progresses.		
Sustainability	**Carbon intensity**	**MEDIUM -** Ongoing energy requirements for pumping and reticulation. However, very high quality and can be used for a variety of end uses with minimal treatment requirements, and associated low-energy intensity of treatment.		
	Blue-green space provided	**NONE**		
	Climate Resilience	**MEDIUM -** Climate dependant water supply with the requirement for substantial water storage volumes to mitigate seasonal fluctuations in water availability. However, presents an alternative supply option to decrease reliance on centralised system.		
	Surface water quality	**MEDIUM -** Reduced hardscape discharge to drainage system.		

5.6 Grey Water Recycling

5.6.1.1 Grey water is wastewater that excludes toilet waste and is therefore of a higher quality than sewage. It includes waste from uses such as hand washing and showering. Water is collected using separate plumbing (to the standard sewage system), stored, treated and redistributed for non-potable use. Due to the potential for contaminants and pathogens to be present in grey water, it requires a higher level of treatment than rain water. This will include some form of filtration, biological treatment and disinfection, generally undertaken within a package treatment unit. A significant advantage of grey water as a supply option is that it is largely climate independent, so is more reliable and therefore requires reduced storage volumes. It should be noted that combined storage and reuse of rainwater greywater and storm water is possible, and can result in increased consistency of water supply and reduced capital costs (see section 10). In order to facilitate cost savings these features use the same storage volume for recycled greywater and storm attenuation, discharging recycled volumes in anticipation of storm events, using intelligent control systems.

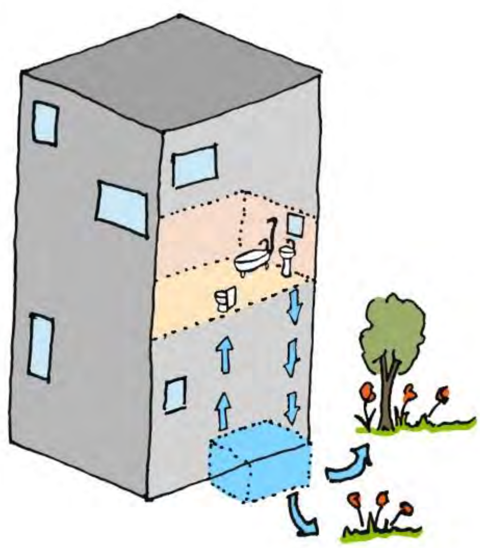


Figure 18 - Plot scale grey water reuse

5.6.1.2 Recycling of greywater is a localised solution to significantly reduce booth foul water flows, and potable demands. As such, this is scalable and avoids many of the feasibility challenges associated with area-scale recycling. However, there are likely to be cost savings and energy efficiencies in installing localised systems within all buildings across the development areas.

5.6.1.3 Innovation in Grey Water Recycling

5.6.1.4 *Grey water recycling* – Grey water recycling has developed from very small scale direct reuse and short retention systems with limited application to large block scale approaches. Although chemical systems have been developed, hybrid bio-mechanical systems with UV treatment offer perhaps the most sustainable application. They use a combination of biological treatment using bacteria and microbes to break down solid waste as well as membrane filtration.

<table>
<tr><th></th><th></th><th>Park Royal - Retained</th><th>Park Royal - New Build</th><th>Old Oak Common</th></tr>
<tr><td rowspan="2">Characteristics</td><td>Assumed Technology</td><td rowspan="6">Unlikely to be feasible for existing buildings due to the plumbing requirement for dedicated greywater collection pipework and non-potable redistribution pipework. May be appropriate for refurbishments or new developments.</td><td>Installation of building scale greywater recycling and non-potable re-use systems for all new buildings.</td><td>Installation of building scale greywater recycling and non-potable re-use systems for all new buildings.</td></tr>
<tr><td>Applicable Scale</td><td colspan="2">Likely to be most feasible at a building scale or sub-area (development) scale.</td></tr>
<tr><td rowspan="3">Core Objectives</td><td>Potential Potable Water Savings</td><td>HIGH - Up to 27% reduction in demand (63 ML/year)</td><td>HIGH - Up to 21% reduction in demand (642 ML/year)</td></tr>
<tr><td>Potential Discharge Reduction</td><td>MEDIUM - Up to 16% reduction of total drainage discharge (63 ML/year)</td><td>MEDIUM - Up to 17% reduction of total drainage discharge (642 ML)</td></tr>
<tr><td>Potential Attenuation Contribution</td><td colspan="2">NONE</td></tr>
<tr><td rowspan="5">Feasibility</td><td>Indicative Cost</td><td>MEDIUM - Estimated 1-2% of capital construction cost (£8,000,000)</td><td>HIGH - Estimated 2-3% of capital construction cost (£95,000,000)</td></tr>
<tr><td>Spatial requirements</td><td colspan="3">LOW - Storage, treatment and distribution infrastructure integrated within building design. Minimal storage volumes are required due to consistency of supply. Below ground tanks can also minimise any additional land take.</td></tr>
<tr><td>Maintenance Requirements</td><td colspan="3">MEDIUM - Inspection and cleaning of collection and treatment systems including filters valves and pumps.</td></tr>
<tr><td>Regulatory and Public Acceptability</td><td colspan="3">MEDIUM - Potential for some public perception issues and regulatory barriers, depending on proposed end uses.</td></tr>
<tr><td>Flexibility and scalability</td><td colspan="3">HIGH - Highly scalable system with minimal space requirements.</td></tr>
<tr><td rowspan="4">Sustainability</td><td>Carbon intensity</td><td colspan="3">HIGH - Ongoing energy and maintenance requirements. Potential for lost efficiencies through delivery of numerous localised solutions.</td></tr>
<tr><td>Blue-green space provided</td><td colspan="3">NONE</td></tr>
<tr><td>Climate Resilience</td><td colspan="3">HIGH - Highly consistent supply of water with low climate dependency, resulting in minimal storage requirements.</td></tr>
<tr><td>Surface water quality</td><td colspan="3">LOW - Marginal benefit through reduced flows to sewer, with reduced associated impact on downstream receiving waterbodies.</td></tr>
</table>

5.7 Green Source Control Measures

5.7.1.1 Implementing Sustainable Urban Drainage Systems (SuDS) aims to recreate more natural drainage systems within the urban environment. These features celebrate the presence of water, enriching the urban environment, while providing valuable function for flood alleviation and biodiversity enhancement. At the plot or development (sub-area) scale, source control measures look to maximise permeable surfaces within the site in an effort to increase the amount of water that is attenuated, treated and processed within the natural hydrological cycle. As such, incorporating features such as raingardens, filter strips, swales and tree pits will assist in absorbing runoff generated within the development, reducing flooding, improving water quality, providing irrigation for vegetation and improve amenity. Such features can also contribute to a range of wider benefits, including provision of habitat for biodiversity, improved air quality and amelioration of the urban heat effect.

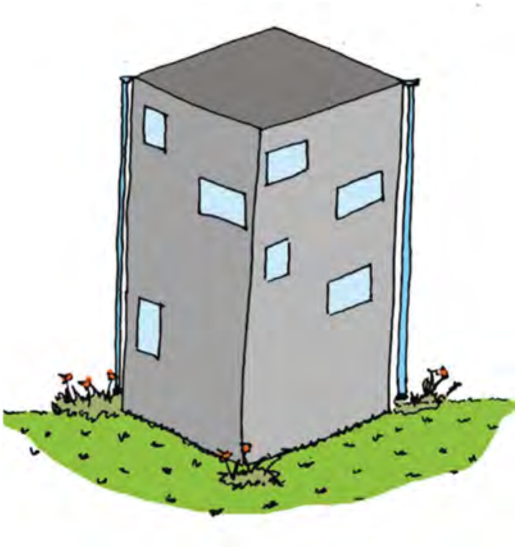


Figure 19 - Plot scale raingardens

5.7.1.2 Incorporation of these measures will contribute towards providing the required attenuation storage, and reducing the volume of storage required. Managing surface water quality and quantity on site will be also be essential to the successes of any downstream measures, preventing inundation of surface water conveyance networks and effectively managing water quality throughout the development. Many SuDS measures are designed to promote infiltration of runoff into the ground beneath, promoting recharge of the water table and reducing runoff. However, these types of measures are unlikely to be suitable within the development site due to the underlying geology, which is largely impermeable (as well as contamination risk in some areas). Therefore, SuDS features will need to be focused on surface water storage and attenuation. While grassed, permeable surfaces should be encouraged on the site; any incorporated SuDS features designed to collect and transport water should be lined so as to transport water to an area where it can be safely disposed. While green measures such as those described above are preferred, hardscape systems like permeable paving, canals, rills and underground storage may be suitable, given the spatial constraints of the site.

5.7.1.3 Within new developments, there are opportunities to provide multi-functional green-blue infrastructure, incorporated within the landscaping of the site. Within the retained development areas, SuDS measures would need to be retrofitted to manage runoff, which increases construction costs. The current land uses are likely to be of a density where this is achievable; however, the feasibility of options may be constrained by the existing site layouts, topography and drainage infrastructure.

5.7.1.4 Innovation in SuDS

5.7.1.5 Despite a long period of uncertainty surrounding the legislative and regulatory requirements for sustainable drainage systems, the National Planning Policy Framework (NPPF), the London Plan and local planning policy has long advocated the consideration of SuDS. The recently released update of the SuDS Manual (2015)[6] highlights that SuDS can contribute to water management objectives on any site, although some sites with specific challenges, such as gradient, low infiltration rates or contamination will have a more limited suite of potential approaches. Most SuDS are, in themselves, relatively straight forward in design. However, consideration of drainage solutions often occurs late in the master planning process; generally once plot areas and GFA have been calculated. Innovation really occurs in the developing a holistic approach to a SuDS train – a network of different SuDS – from the outline design by following where possible the sites natural hydrology to inform design decisions and guide the character of the public realm. This is a process known as WSUD. CIRIA's UK WSUD Scoping Study (2013) and associated ideas book highlights how this approach applies to different urban character

[6] SuDS Manual, CIRIA (2015) - http://www.susdrain.org/resources/ciria-guidance.html

areas[7]. By considering SuDS early in this way as in this integrated water management strategy, they can provide a more meaningful contribution to controlling runoff rates, improving water quality and increasingly provide a source of water reuse in the most cost effective way.

5.7.1.6 The updated SuDS Manual includes details of a number of proprietary treatment products and SuDS approach. Some key emerging themes and products include:

- *Bioretention and manufactured soils* – The accepted approach to bioretention using a loamy soil filtration layer with a geotextile layer transition has less than desirable water quality performance and invariably the geotextile layer can become clogged. Building on research by the likes of Wong and Ford, the new SuDS manual recognises that emerging new generation of engineered soils coming to market can offer greater resilience to blockages and improved water quality.
- *Tree Pits and rain gardens* – Similarly, although tree pits and rain gardens are well understood in their ability to provide attenuation and preliminary treatment, they are not widely used. Concerns around invasive roots and salt damage are often cited as reasons for not using them, although these challenges can be overcome.
- *Crate systems* – Although crate systems, such as Permavoid, have been available for a reasonable length of time they are increasingly being used in a wider range of applications, such as blue roofs.
- *Thirsty concrete* – Hard, durable permeable surfacing has traditionally focused on block pavers which are generally not acceptable forms of surfacing to be adopted by local and highway authorities. Tarmac has recently developed Topmix Permeable, a new permeable concrete that they claim can absorb up to 4,000l of water in the first minute of saturation. It works by using a new form of permeable top layer concrete which allows water to drain into a matrix of large pebbles and then down into a loose base of rubble beneath. Although this has been coupled with drainage networks to help restore ground water, where there is a high water table or impermeable sub-soils, such London clay, alternative approaches to below ground storage may be required. The concrete is however easily damaged by freezing conditions.

Figure 5-6 - Thirsty Concrete (Source: Tarmac)

[7] http://www.ciria.org/Resources/Free_publications/Water_Sensitive_Urban_Design.aspx

		Park Royal - Retained	Park Royal - New Build	Old Oak Common
Characteristics	**Assumed Technology**	Retrofit of SuDS features (bio-retention systems) and 30% additional permeable surface on all existing land parcels.	Installation of SuDS bio-retention systems and 30% additional permeable surface on all new development plots.	Installation of SuDS bio-retention systems and 30% additional permeable surface on all new development plots.
	Applicable Scale	Plot or development scale.		
Core Objectives	**Potential Potable Water Savings**	**NONE**		
	Potential Discharge Reduction	**MEDIUM -** Estimated reduction of 11% of overall drainage discharge (237 ML/year)	**LOW -** Estimated reduction of 3% of overall drainage discharge (11.5 ML/year)	**LOW** - Estimated reduction of 1% of overall drainage discharge (24 ML/year)
	Potential Attenuation Contribution	**LOW -** Dependent on extent and type of features implemented. Estimated storage of approximately 2% of required attenuation.	**LOW -** Dependent on extent and type of features implemented. Estimated storage of approximately 2% of required attenuation.	**LOW** - Dependent on extent and type of features implemented. Estimated storage of approximately 1% of required attenuation.
Feasibility	**Indicative Cost**	**VERY HIGH -** Estimated 3+% of capital construction cost (£149,000,000)	**HIGH -** Estimated 2-3% of capital construction cost (£13,000,000)	**LOW -** Estimated 0-1% of capital construction cost (£27,500,000)
	Spatial requirements	**MEDIUM -** Reasonable surface spatial requirements, which may be difficult to achieve given the high density nature of the proposed development. However, this may be integrated within site landscaping and delivered to provide multiple benefits,		
	Maintenance Requirements	**MEDIUM -** Regular inspection and maintenance, including removal of litter and debris and vegetation management.		
	Regulatory and Public Acceptability	**HIGH -** Supported by current planning policy and potential to provide recreational and amenity benefit.		
	Flexibility and scalability	**HIGH -** Scalable, with the ability for gradual implementation.		
Sustainability	**Carbon intensity**	**LOW -** Potential for carbon sequestration.		
	Blue-green space provided	**HIGH -** provision of green space, with the potential to provide recreational and amenity benefit, habitat for biodiversity, improved air and water quality and microclimate benefits.		
	Climate Resilience	**MEDIUM -** Provision of attenuation and vegetation to assist in mitigating the impacts of climate change on drainage. Capacity design for increased storm intensity will be required.		
	Surface water quality	**HIGH -** Vegetated systems providing water quality benefits through filtration and bio-retention.		

5.8 Below Ground Storage

5.8.1.1 Underground geo-cellular storage can be implemented within site drainage systems to control and manage runoff generated on the site. These systems can be designed to withstand traffic loads, meaning that they can be installed under roads and car parks as well as recreational areas and other public open space. During high intensity rainfall events, these facilities provide on-site attenuation, restricting outflow to avoid overloading the drainage system. Installed in isolation, these structures will not have any benefit in reducing total discharge to the sewer system; however, by restricting the peak instantaneous discharge rates during storm events, they contribute to preventing flooding issues. Stormwater attenuation tanks may be combined with storage for greywater or rainwater recycling systems, resulting in cost efficiencies and, if appropriate treatment measures are in place, reused for non-potable supply.

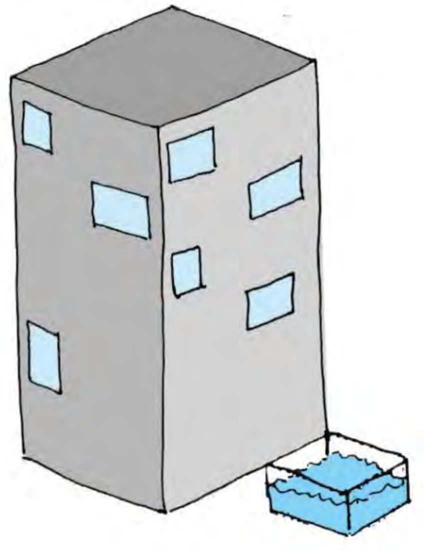


Figure 21 - Underground stormwater attenuation

5.8.1.2 Underground storage does not deliver the additional benefit associated with green infrastructure; however, may provide a practical means of achieving the required attenuation volumes, particularly within development plots, which are likely to be extremely spatially constrained. There is also likely to be some opportunity to install below ground attenuation within the retained properties across Park Royal. However, this would likely require bespoke solutions, and will be limited by constraints of the existing infrastructure.

		Park Royal - Retained	Park Royal - New Build	Old Oak Common
Characteristics	**Assumed Technology**	Retrofit of geo-cellular storage within existing properties providing attenuation to achieve greenfield runoff rates.	Installation of geo-cellular storage within development plots, providing attenuation to achieve greenfield runoff rates.	Installation of Geo-cellular storages within development plots, providing attenuation to achieve greenfield runoff rates.
Characteristics	**Applicable Scale**	Plot or development scale is likely to be most suitable.		
Core Objectives	**Potential Potable Water Savings**	**NONE**		
Core Objectives	**Potential Discharge Reduction**	**NONE**		
Core Objectives	**Potential Attenuation Contribution**	**HIGH -** Potential to provide up to 100% of required dispersed or collective attenuation, if delivery is feasible.	**HIGH -** Potential to provide up to 100% of required dispersed or collective attenuation, if delivery is feasible.	**HIGH -** Potential to provide up to 100% of required dispersed or collective attenuation, if delivery is feasible.
Feasibility	**Indicative Cost**	**VERY HIGH** - Estimated 3+% of capital construction cost (£212,000,000)	**HIGH** - Estimated 2-3% of capital construction cost (£15,000,000)	**LOW** - Estimated 0-1% of capital construction cost (£12,000,000)
Feasibility	**Spatial requirements**	**LOW -** Significant volumes are required to meet Greenfield runoff rates. However, underground installation minimises effective land requirements.		
Feasibility	**Maintenance Requirements**	**MEDIUM -** Regular inspection of silt traps, manholes, pipework and pre-treatment devices, with removal of sediment and debris as required.		
Feasibility	**Regulatory and Public Acceptability**	**HIGH -** Supported by current planning policy and potential to provide recreational and amenity benefit.		
Feasibility	**Flexibility and scalability**	**HIGH -** Scalable, with the ability for gradual implementation. Below ground installation limits flexibility, and opportunities may be limited by, or impact upon, the deliverability of other underground infrastructure.		
Sustainability	**Carbon intensity**	**LOW -** minimal ongoing energy requirements.		
Sustainability	**Blue-green space provided**	**NONE**		
Sustainability	**Climate Resilience**	**MEDIUM -** Provision of attenuation to assist in mitigating the impacts of climate change on drainage. Capacity design for increased storm intensity will be required.		
Sustainability	**Surface water quality**	**MEDIUM -** Some water quality benefit provided through storage, sedimentation and reduced drainage flows; however, limited benefit as opposed to above ground surface water management.		

5.9 Strategic SuDS Networks

5.9.1.1 A strategic surface water network will be required across the Opportunity Areas to manage and convey surface water, while providing attenuation and water quality treatment. As an alternative to traditional underground, piped systems, this may be delivered using a connected sequential train of SuDS features, such as swales, filter strips and flow spreaders. Providing several SuDS features in a series will enhance treatment as the slowed water passes the different features and treatment mechanisms. The infrastructure will also have a range of positive benefits to the urban environment, through improved aesthetics, air and water quality, microclimate management and biodiversity benefit. The capacity of the network must be sufficient to drain roads and public space, while conveying water collected from plots, to downstream locations for storage, harvesting or discharge. As such, the required configuration will be strongly influenced by selected option for stormwater discharge, and the balance of on-plot to downstream attenuation.

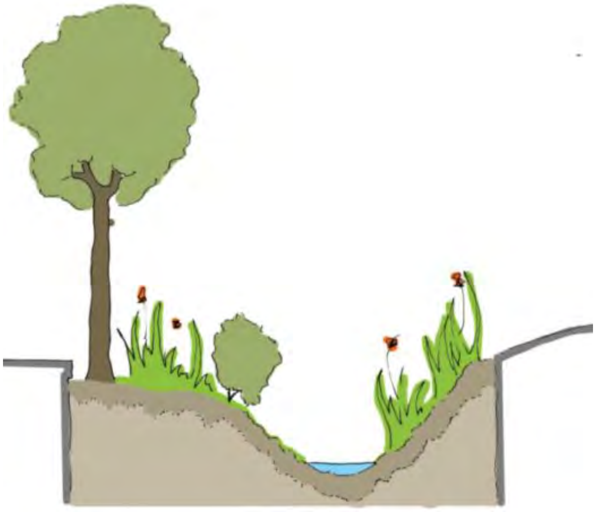


Figure 22 - Streetscape swales

5.9.1.2 The design and configuration of the streetscape network would require detailed consideration of spatial availability and constraints, topography, water quality and discharge. Desirably, the street network should be flexibly designed around the natural hydrology of the area, with overall site levels rationalised in order to facilitate natural drainage pathways over as much of the area as possible. The presence of extensive rail infrastructure and the canal may place constraints on the ability to install comprehensive networks, by fragmenting the surface connectivity of the catchment which may require the installation of supporting conventional underground infrastructure. Availability of space may present a significant challenge; however, a network of public green space is proposed to be delivered with the regeneration proposals, which may provide opportunities for distributed blue-green infrastructure within the streetscape and public spaces.

5.9.1.3 Within retained areas of the Opportunity Areas, the installation of SuDS within the streetscape will be even more constrained by the existing infrastructure and spatial limitations, so it is unlikely that this could initially entirely replace conventional drainage infrastructure. However, there are likely to be opportunities for local collection of stormwater in strategically located green infrastructure integrated within the streetscape, utilising tree planting, traffic calming, parking bays, verges and central reservations. The provision of these landscaped features could be used to capture surface water runoff from roofs and road, providing attenuation and treatment before discharge to the sewer system. Porous paving and hardscape solutions may also be appropriate in this area.

		Park Royal - Retained	Park Royal - New Build	Old Oak Common
Characteristics	**Assumed Technology**	Retrofit of green infrastructure within the streetscape to collect, attenuate and convey storm water.	Extensive SuDS networks installed in the place of conventional drainage systems to drain all roads and public space.	Extensive SuDS networks installed in the place of conventional drainage systems to drain all roads and public space.
	Applicable Scale	Assumed area wide; however, may also be appropriate for development scale.		
Core Objectives	**Potential Potable Water Savings**	**NONE**		
	Potential Discharge Reduction	**LOW** - Reduced volume of surface water discharge through enhanced evapotranspiration and biological uptake.	**LOW** - Reduced volume of surface water discharge through enhanced evapotranspiration and biological uptake.	**LOW** - Reduced volume of surface water discharge through enhanced evapotranspiration and biological uptake.
	Potential Attenuation Contribution	**LOW -** Dependent on installed features and spatial availability. Estimated minimum of 5% of required attenuation volume is achievable.	**MEDIUM -** Approximately 13% of attenuation required, dependant on spatial availability.	**HIGH** - Estimated 42% of attenuation required could be provided dependant on spatial availability.
Feasibility	**Indicative Cost**	**HIGH -** Estimated 2-3% of capital construction cost £23,000,000	**LOW -** Estimated 0-1% of capital construction cost (£800,000)	**LOW -** Estimated 0-1% of capital construction cost (£4,000,000)
	Spatial requirements	**MEDIUM -** Reasonable surface spatial requirements, which may be difficult to incorporate into the dense development areas, and particularly challenging to retrofit in existing areas. However, this may be integrated within site landscaping and delivered to provide multiple benefits.		
	Maintenance Requirements	**MEDIUM -** Litter and debris clearance and removal, vegetation management, monitoring and repair of damaged or degraded areas. Above ground systems can increase the ease of identifying and undertaking required repairs.		
	Regulatory and Public Acceptability	**MEDIUM -** Multi-functional infrastructure can enhance the streetscape and public realm. Determining responsibility for ongoing maintenance may present some barriers.		
	Flexibility and scalability	**MEDIUM -** Delivery can likely be phased in line with construction of the street network; however, early consideration of topography, street layout and discharge is required to maximise benefit.		
Sustainability	**Carbon intensity**	**LOW -** Maximises passive conveyance and treatment by harnessing natural catchment hydrology. Potential for carbon sequestration.		
	Blue-green space provided	**HIGH -** provision of green space, with the potential to provide recreational and amenity benefit, habitat for biodiversity, improved air and water quality and microclimate benefits.		
	Climate Resilience	**MEDIUM -** Provision of attenuation and increased permeability to assist in mitigating the impacts of climate change on drainage. Capacity design for increased storm intensity will be required.		
	Surface water quality	**HIGH -** Promote evaporation and absorption of surface water and reduced pollutant loads through filtration and biological degradation. Drainage from industrial areas may contain high contaminants of pollutants which will require management.		

5.10 Waterway Storage and Discharge

5.10.1.1 There are two significant waterways within the immediate vicinity of the Opportunity Areas. These are the Grand Union Canal, running through the centre of both Areas, and the River Brent, running along the western boundary of the Park Royal. Currently, the western extents of Park Royal, within Thames Water's Mogden sub-catchment, discharges surface water to the River Brent. To avoid overloading or exacerbating the sewer flooding issues within the Counters Creek catchment, it may be possible to modify the surface water catchment areas to discharge a greater area of (retained) Park Royal to the River Brent. Similarly, discharge of surface water within Old Oak Common, and certain areas of Park Royal (including the New Build areas) to the Grand Union Canal may be an option. The natural topography of the Opportunity Areas would likely impact how much of the area would be able to be re-directed to these catchments.

Figure 23 - Stormwater discharge to local waterways

5.10.1.2 Appropriate attenuation and water quality management measures (as described above) would be required to ensure no adverse impacts on the watercourse hydrology and quality. Detailed hydrological analysis would also be necessary to ensure that these measures did not cause any additional flood risk to other areas of the catchments or contribute to pollution or ecological deterioration. Allowable discharge rates and associated impacts on flow regimes, during times of both high and low flow would require investigation. Additionally, particular consideration would be required to manage surface water discharge from industrial areas, which may contain contaminants. Detailed consultation with the Environment Agency, the Canal and The River Trust would be required in further scoping these options.

5.10.1.3 As an alternative to ultimate discharge to these sources, it may be possible to use the Canal or River for temporary storage and conveyance of peak surface water flows, which could be subsequently extracted to avoid any net increase in flows. However, this is likely to require complex pumping mechanisms, and further scoping is required to confirm this as an option.

5.10.1.4 Considering wider discharge options, it may also be possible to inject collected surface water to a below ground aquifer for artificial groundwater recharge. It is understood that there is not an appropriate aquifer located within the immediate vicinity of the site; therefore water would need to be transported outside the site, to a suitable location for injection.

		Park Royal - Retained	Park Royal - New Build	Old Oak Common
Characteristics	**Assumed Technology**	Managed discharge or storage of runoff to the River Brent (or Grand Union Canal), through connection of new sustainable drainage infrastructure.	Managed discharge or storage of runoff to the Grand Union Canal, through connection of new sustainable drainage infrastructure.	Managed discharge or storage of runoff to the Grand Union Canal, through connection of new sustainable drainage infrastructure.
Characteristics	**Applicable Scale**	Development or area wide scale		
Core Objectives	**Potential Potable Water Savings**	**NONE**		
Core Objectives	**Potential Discharge Reduction**	**VERY HIGH -** Up to 80% reduction of total discharge to the drainage system (assuming 100% of surface water discharged)	**VERY HIGH -** Up to 42% reduction of total discharge to the drainage system (assuming 100% of surface water discharged)	**VERY HIGH -** Up to 23% reduction of total discharge to the drainage system (assuming 100% of surface water discharged)
Core Objectives	**Potential Attenuation Contribution**	Potential to provide a significant proportion of required attenuation; however this is dependent on system configuration and requires further hydrological analysis.		
Feasibility	**Indicative Cost**	Unable to be assessed based on current information; however, primary capital costs are likely to be associated with provision of a new surface water drainage network (as discussed above)		
Feasibility	**Spatial requirements**	**LOW -** Minimal, excepting associated spatial requirements for surface drainage and attenuation systems (discussed separately)		
Feasibility	**Maintenance Requirements**	Primary requirements will be as associated with related drainage and attenuation infrastructure. Potential for additional ongoing costs related to discharge.		
Feasibility	**Regulatory and Public Acceptability**	**MEDIUM -** Some regulatory barriers are possible; however, this is considered manageable provided appropriate consultation and the discharge is carefully managed to mitigate any downstream increased flood risk or water quality impacts.		
Feasibility	**Flexibility and scalability**	**MEDIUM -** Provided stakeholder agreement is reached, discharge may be able to be incrementally transferred to different locations, in line with the delivery of the development. However, upfront planning of levels, street layout and discharge locations would be required.		
Sustainability	**Carbon intensity**	**LOW -** removing surface water flows from the sewer system will reduce the volume of being conveyed to downstream treatment plants.		
Sustainability	**Blue-green space provided**	**NONE -** no direct impact; however, this may be provided through delivery of associated drainage infrastructure.		
Sustainability	**Climate Resilience**	**MEDIUM** - removing surface water flows from the sewer system will assist in mitigating the impacts of climate change on drainage.		
Sustainability	**Surface water quality**	**MEDIUM -** moving towards more natural pre-development catchment conditions will assist in mitigating water quality issues associated with CSO overflows; however, potential water quality and waterway health implications will need to be carefully considered and mitigated.		

5.11 Downstream Stormwater Retention Ponds or Wetlands

5.11.1.1 As an alternative to providing localised, on-plot storage of storm water runoff, downstream detention may also be provided. This could be in the form of a dry detention basin or a pond or wetland system, with the potential to provide additional quality and biodiversity benefits. These systems provide attenuation and treatment of storm water runoff, and are designed to support emergent and submerged aquatic vegetation along the shoreline. The retention time promotes pollutant removal through sedimentation and the opportunity for biological uptake mechanisms further reduces concentrations of pollutants. These features also have the potential to provide significant ecological and amenity benefits, while contributing to improved air quality, and amelioration of the urban heat effect.

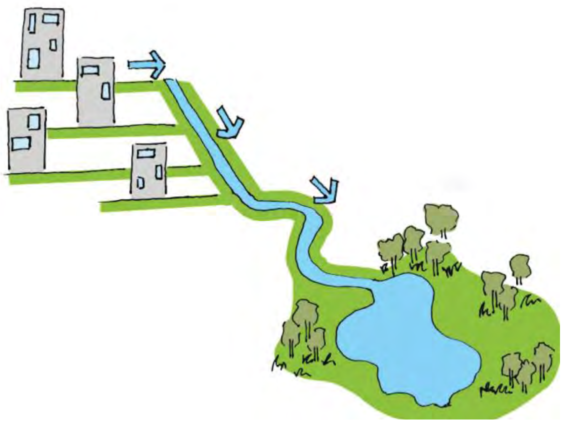


Figure 24 - Downstream stormwater attenuation

5.11.1.2 Significant volumes of water storage would be required to achieve Greenfield rates, which could be provided as a single volume, a series of dispersed volumes, or used in conjunction with other means of providing attenuation. The natural topography of the two Opportunity Areas and the presence of existing drainage systems will impact the required location and contributing catchment of the retention storage. These systems would be most effective if installed in conjunction with upstream SuDS networks, to treat and convey incoming storm flows. The availability of space will be the major constraint in the delivery of surface storages, with further challenges presented by the presence of the canal and rail infrastructure, disrupting the surface connectivity of the catchment.

5.11.1.3 Within retained areas, the availability of space to implement attenuation storage in this area is currently highly limited by the density of exiting developed industrial land uses. It is unlikely that existing space will be readily available, sufficient to provide the storage volumes required. However, as a part of the development proposals, there will likely be opportunities to secure additional community green space, which may provide opportunities for the delivery of dispersed surface water storage and treatment features. Alternatively, land space could be acquired through direct land purchase.

		Park Royal - Retained	Park Royal - New Build	Old Oak Common
Characteristics	**Assumed Technology**	Storm water attenuation provided to the downstream of the hydrological catchment.	Combined storm water attenuation provided to the downstream of the hydrological catchment, servicing Old Oak Common and new build areas of Park Royal.	
	Applicable Scale	Development or area scale. May be delivered as a single storage or multiple dispersed storages across the development areas.		
Core Objectives	**Potential Potable Water Savings**	**NONE**		
	Potential Discharge Reduction	**LOW -** Reduced volume of surface water discharge through enhanced evapotranspiration.	**LOW-** Reduced volume of surface water discharge through enhanced evapotranspiration.	
	Potential Attenuation Contribution	**HIGH -** Up to 100% provided in dispersed or single attenuation.	**HIGH -** Potential to provide up to 100% of required dispersed or collective attenuation, depending on spatial availability.	**HIGH -** Potential to provide up to 100% of required dispersed or collective attenuation, depending on spatial availability.
Feasibility	**Indicative Cost**	**HIGH -** Estimated 3+% of estimated construction costs (£113,000,000)	**LOW -** Estimated 0-1% of estimated construction costs (£28,000,000)	
	Spatial requirements	**HIGH -** Significant spatial requirements. However, this may be integrated within landscaping and delivered to provide multiple benefits for the urban aesthetics, environment and community.		
	Maintenance Requirements	**MEDIUM -** Litter/debris removal and cleaning, vegetation management, sediment monitoring and removal.		
	Regulatory and Public Acceptability	**MEDIUM -** High quality design and delivery is required to prevent safety hazards and issues associated with eutrophication and undesirable aesthetics resulting from fluctuating water levels. Determining responsibility for ongoing maintenance may present challenges.		
	Flexibility and scalability	**MEDIUM -** Site levels would need to be carefully considered in order to facilitate natural surface drainage pathways over as much of the site as possible. Physical barriers, such as infrastructure routes, would need to be navigated.		
Sustainability	**Carbon intensity**	**LOW -** delivery of associated green space may provide potential for carbon sequestration.		
	Blue-green space provided	**HIGH -** provision of blue- green space, with the potential to provide recreational and amenity benefit, habitat for biodiversity, improved air and water quality and microclimate benefits.		
	Climate Resilience	**MEDIUM** - Provision of attenuation to assist in mitigating the impacts of climate change on drainage. Capacity and exceedance design for increased storm intensity and safe containment of flooding will be required.		
	Surface water quality	**HIGH -** Improved surface water quality through attenuation, sedimentation and biological uptake of contaminants.		

5.12 Stormwater Recycling

5.12.1.1 Stormwater treatment and harvesting from urban catchment areas can provide an alternative water source to offset centralised potable demands, while reducing storm flow the sewer system. Stormwater picks up a wide range of pollutants from the surfaces it flows off and its quality is highly variable over time. Typical storm water treatment generally involves some form of filtration to capture the suspended solids and pollutants attached to the sediments followed by disinfection. This is often provided using vegetated systems, designed to use natural, passive processes for filtering pollutants. Supply is variable due to the dependence on rainfall patterns, with significant storage infrastructure likely to be required to manage this, and a back-up water supply connection may additionally be required for particularly dry periods. Water could be supplied for outdoor irrigation use, for specific industrial process or for non-potable uses within residences and businesses.

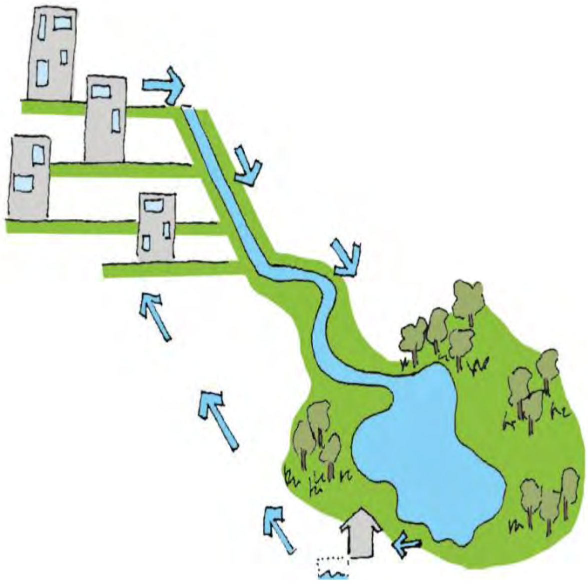


Figure 25 - Stormwater harvesting and reuse

5.12.1.2 This infrastructure would need to be carefully planned in conjunction with the proposed surface water drainage network and masterplan layout with spatial constraints likely to impact upon feasibility of infrastructure delivery in the high density development. Detailed feasibility investigation would additionally be required to determine the exact extent of the hydrological catchment able to contribute, given the spatial fragmentation of the area, due to dividing infrastructure including rail lines and the canal. Significant underground infrastructure could be required to manage this, and maximise the collection of available flows across the Opportunity Areas. Wormwood Scrubs may present an opportunity for installation, due to potential spatial availability and location to the downstream of the new build catchment.

5.12.1.3 Area-scale retrofit of stormwater recycling within retained areas is unlikely to be immediately feasible, due to spatial constraints and the lack of a non-potable distribution network; however, localised solutions for irrigation or outdoor use may be feasible, in conjunction with delivery of surface water attenuation infrastructure. Any new redevelopment or refurbishments could be connected to non-potable recycled supplies provided for adjacent new build areas.

5.12.1.4 Potable re-use of collected storm water may also eventually be possible, with ongoing technological advancements in this area. Long term research, monitoring and assessment of treated water quality would be required in order to deliver this.

		Park Royal - Retained	Park Royal - New Build	Old Oak Common
Characteristics	**Assumed Technology**	A non-potable network solution is unlikely to be immediately feasible for retained areas of Park Royal; however, new redevelopment or refurbishments could be connected to non-potable recycled supplies, as provided for new build areas. Localised solutions for irrigation may be achievable.	Downstream storm water harvesting system incorporating wetland secondary treatment train, disinfection, balancing storage and re-distribution for non-potable re-use.	
	Applicable Scale		Likely to be most appropriate on an area wide or development scale.	
Core Objectives	**Potential Potable Water Savings**		**HIGH -** Up to 21% reduction in potable demand (681 ML/year)	
	Potential Discharge Reduction		**MEDIUM -** Up to 17% reduction in total drainage discharge (681 ML/year)	
	Potential Attenuation Contribution		**VERY HIGH -** Up to 100%, dependant on spatial availability.	
Feasibility	**Indicative Cost**		**MEDIUM -** Estimated 1-2% of anticipated construction costs (£48,000,000)	
	Spatial requirements	**HIGH -** Significant spatial requirements. However, this may be incorporated into urban landscape to provide high quality public realm and opportunities for recreational space and amenity.		
	Maintenance Requirements	**HIGH -** Litter/debris removal, cleaning, vegetation and sediment management. Ongoing operational and energy requirements associated with treatment and distribution.		
	Regulatory and Public Acceptability	**LOW -** Potential public perception issues with re-use of recycled storm water and potential for regulatory barriers, depending on proposed end use.		
	Flexibility and scalability	**LOW** - Centralised system may make it more difficult to phase delivery. Upfront spatial planning and rationalisation of levels and drainage pathways is essential.		
Sustainability	**Carbon intensity**	**HIGH -** Ongoing energy and maintenance requirements for treatment and distribution.		
	Blue-green space provided	**HIGH -** provision of green space, with the potential to provide recreational and amenity benefit, habitat for biodiversity, improved air and water quality and microclimate benefits		
	Climate Resilience	**LOW -** Climate dependant water source, with associated large storage requirements and less reliability of supply.		
	Surface water quality	**HIGH** - attenuation, water quality treatment and removal of urban runoff from the sewer and surface water systems.		

5.13 Wastewater Recycling

5.13.1.1 Wastewater recycling comprises collection of wastewater flows (including both blackwater and greywater), treatment to a high standard, and distribution for non-potable re-use. Wastewater contains a high concentration of contaminants that can present risks to human health. As such, significant processing is required to treat flows to a high quality in order to adequately manage this risk. These treatment processes can be costly and energy intensive, including advanced water treatment technologies, such as microfiltration, reverse osmosis or advanced oxidation, although new processes such as electrocoagulation and food chain reaction may provide more cost effective solutions (see section 10).

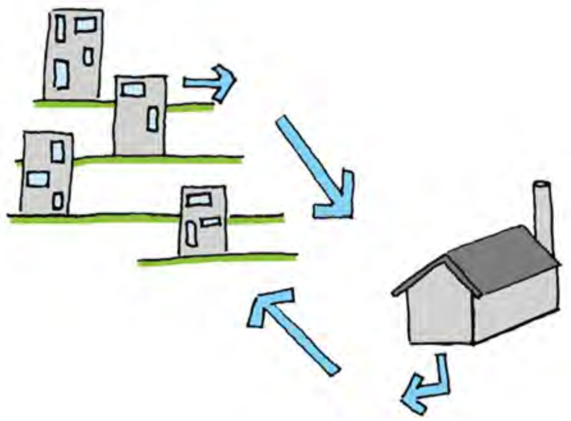


Figure 26 - Wastewater recycling

5.13.1.2 A package wastewater treatment plant could be supplied to collect and treat wastewater flows from the new development areas, and re-supply fit for purpose non-potable water for re-use. Spatial requirements for the new plant would need to be considered, along with management of any potential visual, noise or odour impacts. Ideally, a modular, scalable system could be installed, to allow for gradual expansion with delivery of the development.

5.13.1.3 Treated wastewater is available in significant quantities, and has the potential to provide a highly consistent and reliable supply stream to reduce demands on mains water and waste water discharge. Appropriately treated wastewater may be used for irrigation, process uses, or non-potable reuse within homes and businesses. This could also be exported outside the Opportunity Areas for use in surrounding developments.

5.13.1.4 Currently, direct recycling of wastewater is unlikely to be appropriate due to the numerous barriers necessary to mitigate the health risks associated with water quality. However, in the longer term, this may be possible, with ongoing technological advancements in this area and a changing socio-institutional climate. Under this scenario, wastewater has the potential to offset almost all potable demand, presenting an important advantage in terms of flexibility for future technological advancement (as compared to the other recycling options).

5.13.1.5 Innovation in Waste Water Recycling

5.13.1.6 *Hydro Industries Electrocoagulation* – Electrocoagulation is a technology that separates dissolved particles from water and has demonstrable application in the oil and gas industry where it is used primarily for remediation. As the technology is developing it is becoming increasingly viable for use in domestic waste water treatment. It works by passing a low voltage current through waste water to produce an extra hydrogen molecule which destabilises the charge holding heavy metals, organics and inorganics in solution. These then separate and can be mechanically removed.

5.13.1.7 Hydro Industries have developed a modular electrocoagulation plant, each processing in the region of 1,400m^3 – 2,900m^3 per unit a day depending on discharge quality required. The modular design means that the plant can be scaled as the development demands change from construction through operation and decommissioning. Alternatively it can form part of a very localised distributed system. The process is effective at removing a wide range of contaminants and has a number of applications for treating industrial waste water. As such, there could be potential for location in Park Royal. Hydro Industries have also used electrocoagulation to produce potable drinking water in India and area currently working with Welsh Water, Affinity Water, Wessex Water, United Utilities and Northumberland Water to trail the use of electrocoagulation, primarily for solids-metal removal as part of the drinking water treatment process.

Figure 5-13 - Hydro Industries, HydroCurrent (Source Hydro Industries)

5.13.1.8 *Living Machine®* - The Living Machine® such as the one used at the headquarters of San Francesco, mimics wetland ecology to treat waste water. The waste water passes through a series of 'wetland cells' which contain filtration media that promote the growth of organisms in 'micro-ecosystems' that remove the nutrients and solids from the waste water. This system is known as a tidal system and the wetland cells are routinely flooded and drained several times a day. These systems can be integrated into greenhouses and the public realm as all the treatment processes occur below the wetland surface with attractive wetland vegetation at the surface.

5.13.1.9 *Organica Food Chain Reactor (FCR)* – The FCR is an advanced variation of the traditional activated sludge approach to waste water treatment plant. Designed to provide more localised treatment of waste water for an urbanising world, Organica's FRC approach has been shown to reduce the physical footprint by 50%, energy demand by 30% and waste sludge by 35% when compared with traditional waste water management. The reduction in required size, associated construction costs and the waste sludge generated is down to an increase in density and diversity of the biomass used to breakdown the solid waste by creating a more varied ecosystem. This is achieved by introducing vegetation and engineered biomedia into the reaction tanks. The root system of the planting and the biomedia create a biofilm habitat that can accommodate about four times the number of organisms to digest and metabolise the waste. In turn, these microbes and bacteria are predated upon and metabolised by larger organisms, as the food chain reaction is activated.

5.13.1.10 For the organisms in any activated sludge process they need to be able to absorb oxygen from the waste water. As such, aeration of the waste water is one of the biggest operational costs of activated sludge treatment. The FCR reduces energy demand by significantly reducing the aeration requirements in two ways. Firstly, the structure of the root system and biomedia creates a biofilm with a much greater surface area, allowing oxygen to be absorbed more efficiently. Because the root structure and biomedia and therefore biomass are in fixed locations, as opposed to floating within the waste water, the waste water has less particulate matter in it. This in turn allows the oxygen from the aeration to be dissolved more efficiently as well.

5.13.1.11 By locating and treating water close to where it is generated also reduces the energy and costs associated with pumping waste water over large distances. It also offers the potential for reuse as a non-potable water source and there are a number of FCR plants in China which utilise the treated sewage effluent to flush toilets.

5.13.1.12 The FRC can be located within urban areas because it is odour free and has the appearance of an attractive botanical greenhouse. Although the physical buffer zones can be less than 20m, the attractive, planted nature of the plant also means that the psychological barriers often associated with waste water treatment are removed. The replacement of the South Pest WWTW with an 80,000m^3/day FRC unlocked a large area of development land previously taken up by the former plant and buffer area.

Figure 5-14 - Organica's 80,000m^3 plant in South Pest (source: Organicawater.com)

Figure 5-15 - 2,000m^3 waste water treatment plant, Jakata (source: Organicawater.com)

<table>
<tr><th></th><th></th><th>Park Royal - Retained</th><th>Park Royal - New Build</th><th>Old Oak Common</th></tr>
<tr><td rowspan="2">Characteristics</td><td>Assumed Technology</td><td rowspan="6">A non-potable network solution is unlikely to be feasible for retained areas of Park Royal; however, new redevelopment or refurbishments could be connected to non-potable recycled supplies, as provided for new build areas.</td><td colspan="2">Package wastewater treatment plant to treat incoming sewage, incorporating advanced water treatment, and redistribution for non-potable reuse within homes and businesses.</td></tr>
<tr><td>Applicable Scale</td><td colspan="2">Area scale. Building or development scale wastewater recycling systems are also possible; however, greywater recycling is likely to be more appropriate in this instance.</td></tr>
<tr><td rowspan="3">Core Objectives</td><td>Potential Potable Water Savings</td><td colspan="2">HIGH - Up to 21% reduction in potable demand (681ML/year)</td></tr>
<tr><td>Potential Discharge Reduction</td><td colspan="2">MEDIUM - Up to 17% reduction in total drainage discharge (681ML/year)</td></tr>
<tr><td>Potential Attenuation Contribution</td><td colspan="2">NONE</td></tr>
<tr><td rowspan="5">Feasibility</td><td>Indicative Cost</td><td colspan="2">LOW - Estimated 0-1% of anticipated construction costs (£44,000,000)</td></tr>
<tr><td>Spatial requirements</td><td colspan="3">MEDIUM - Spatial requirements associated with infrastructure for wastewater collection, treatment, storage and distribution.</td></tr>
<tr><td>Maintenance Requirements</td><td colspan="3">HIGH - Ongoing operational and energy requirements associated with treatment and distribution.</td></tr>
<tr><td>Regulatory and Public Acceptability</td><td colspan="3">LOW - Potential public perception issues with re-use of recycled storm water and potential for regulatory barriers, depending on proposed end use. Potential community concerns associated with potential for noise and odour (these can be mitigated)</td></tr>
<tr><td>Flexibility and scalability</td><td colspan="3">MEDIUM - May be more difficult to phase delivery in line with development; however, new technologies have the potential for innovative designs with modular composition.</td></tr>
<tr><td rowspan="4">Sustainability</td><td>Carbon intensity</td><td colspan="3">HIGH - Ongoing energy and maintenance requirements.</td></tr>
<tr><td>Blue-green space provided</td><td colspan="3">LOW - Minimal provided through traditional design. However, new technologies may provide opportunities for use of green, biological treatment processes.</td></tr>
<tr><td>Climate Resilience</td><td colspan="3">HIGH - Highly reliable supply with limited climate dependence.</td></tr>
<tr><td>Surface water quality</td><td colspan="3">LOW - Marginal benefit through reduced flows to sewer, with reduced associated impact on downstream receiving waterbodies.</td></tr>
</table>

5.14 Expansion of the Counters Creek Flood Alleviation Scheme

5.14.1.1 The public sewer system in central London was constructed to accommodate foul water (from toilets, showers and sinks) as well as surface water (from roofs and driveways) in the same pipe. The sewers are therefore called "combined" sewers as they accommodate a combination of both foul and surface water flow.

5.14.1.2 The available capacity of these sewers varies significantly depending on precipitation. During heavier rainfall events the local sewers as well as the interceptor sewers run out of capacity and begin to surcharge. To prevent properties from flooding during heavy rainfall a network of deep "storm relief" sewers were constructed over time. These sewers take excess flow from the interceptor sewers and relay this flow directly to the River Thames via a combined sewer overflow (CSO). These direct connections into the environment are going to be addressed by the construction of the Thames Tideway Tunnel which will significantly improve the river water quality by preventing discharge from the storm relief sewers directly into the environment.

5.14.1.3 The Counters Creek programme includes the construction of a new storm relief sewer to prevent property flooding in Hammersmith, Fulham, Kensington and Chelsea where significant property flooding has been observed. This solution will allow excess storm flows in the interceptor sewers to spill into it, and will eventually connect to the Thames Tideway Tunnel to ensure that we do not increase combined sewer overflows into the River Thames.

5.14.1.4 Any growth and redevelopment opportunities will increase the dry weather flow into the public sewer system. Development at Old Oak Common can therefore not be accommodated into the new Counters Creek storm relief sewer as that has the potential to initially yield a discharge of dry weather flow directly into the environment through a combined sewer overflow or be incorporated into the flow that the Thames Tideway Tunnel needs to accommodate. The use and operation of all combined sewer overflows as well as the Thames Tideway Tunnel are regulated by the Environment Agency and a dry weather flow discharge from growth would be a breach of these discharge permits.

5.14.1.5 As such, this is not considered to be a feasible option to manage the increase in foul water flow from Old Oak Common and Park Royal. The preferred approach is to returning capacity in the local and interceptor sewers by removing surface water, using SuDS techniques.

		Park Royal - Retained	Park Royal - New Build	Old Oak Common
Core Characteristics	**Assumed Technology**	Expansion of the Counters Creek Flood Alleviation Scheme to provide additional conventional drainage capacity across the Opportunity Areas.		
	Applicable Scale	Regional scale solution		
Core Objectives	**Potential Potable Water Savings**	**NONE**		
	Potential Discharge Reduction	**NONE**		
	Potential Attenuation Contribution	**LOW -** Some in-system storage could be provided for stormwater attenuation		
Feasibility	**Indicative Cost**	**VERY HIGH -** The cost for this option is unknown; however, likely to be significantly in excess of any of the other options described.		
	Spatial requirements	**LOW -** No surface spatial requirements; however, significant surface construction footprints would likely be required.		
	Maintenance Requirements	**MEDIUM -** Conventional drainage system maintenance		
	Regulatory and Public Acceptability	**LOW -** Potential breach of Environment Agency discharge conditions for CSOs and likelihood of highly disruptive construction at significant cost.		
	Flexibility and scalability	**LOW** - Reinforcement of centralised infrastructure.		
Sustainability	**Carbon intensity**	**HIGH -** operational emissions associated with pumping flows out for treatment; however, a highly intensive construction process is likely to be required.		
	Blue-green space provided	**NONE**		
	Climate Resilience	**LOW -** Provides increased capacity for increased rainfall intensity; however, reinforces the hydrological impacts of conventional drainage systems.		
	Surface water quality	**NONE -** May contribute to combined sewer overflows		

6 Water Management Options

6.1 Strategy Formulation

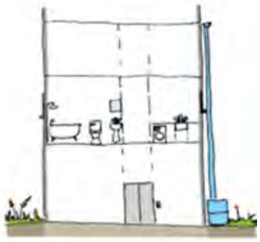
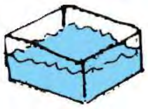
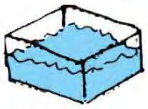
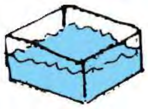
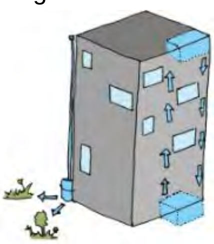
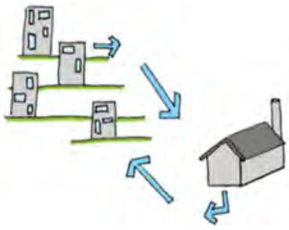
6.1.1.1 In order to address the significant challenges of the Opportunity Area development, a suite of measures will be required to be delivered in combination. The majority of measures introduced in Section 5 are scalable and complementary, or address separate aspects of the urban water cycle. Furthermore, several of these measures should be delivered within the development as standard best practice; whilst for others there are various available options/approaches.

6.1.1.2 Table 6-1 below provides an overview of how the various measures could t be alternatively combined, to create different water management scenarios. Six scenarios have been generated, representing different options and combinations of the various strategy aspects, as further discussed in the following sections.

6.1.1.3 In order to meet the extensive challenges of the proposed development, all of these scenarios incorporate the following components:

- Achieving the maximum possible standards of demand management, by achieving the highest current and future industry standards in water efficiency, utilisation of smart network technologies, community engagement and targeted water efficiency retrofits and process improvements.
- A cohesive integrated approach to manging surface water quality and quantity, including attenuation, conveyance and discharge of runoff, across the development areas. The options available for surface water management are discussed in Section 6.3, below.
- A strategic approach to water recycling, considering non-potable use of water as a minimum, with allowance for future implementation of potable water recycling. Options available for water re-use are discussed in Section 6.4, below.

Table 6-1: Water Management Scenarios

<table>
<tr><td rowspan="6">Strategy Components</td><td>Demand Management</td><td colspan="6">Maximising demand management through water efficiency, community engagement and utilisation of smart network technologies. </td></tr>
<tr><td rowspan="3">Stormwater Management Options</td><td colspan="6">Green source control features to manage the quality and quantity of surface water generated on site. </td></tr>
<tr><td colspan="6">Streetscape strategic SuDS network providing conveyance, filtration and attenuation of stormwater from development plots to attenuation or discharge locations. </td></tr>
<tr><td>Residual attenuation provided underground </td><td>Residual attenuation provided above ground </td><td>Residual attenuation provided underground </td><td>Residual attenuation provided above ground </td><td>Residual attenuation provided underground </td><td>Residual attenuation provided above ground </td></tr>
<tr><td>Water Recycling Options</td><td colspan="2">Building scale greywater recycling </td><td colspan="2">Strategic scale wastewater recycling </td><td colspan="2">Strategic scale stormwater recycling </td></tr>
<tr><td></td><td>Scenario 1</td><td>Scenario 2</td><td>Scenario 3</td><td>Scenario 4</td><td>Scenario 5</td><td>Scenario 6</td></tr>
</table>

6.2 Multi-Criteria Analysis

6.2.1.1 In order to evaluate the various options for the surface water management and water recycling components, a process of Multi-Criteria Analysis (MCA) has been undertaken, using the performance criteria defined in Section 5.2. Each of the formulated strategy options has been selected to maximise the achievement of the core project objectives as far as possible. The qualitative assessment of each of the feasibility and sustainability criteria were translated into a comparative score between 0 and 3, and a relative weighting applied to each criteria, as shown in Table 6-2 below. These weightings have been defined to be reflective of discussions held with key project stakeholders and representative of the overall priorities for water management across the Opportunity Areas. The cumulative scores for each measure were then compared to determine the order of preference between the different measures for each function.

Table 6-2: Weightings applied to each performance criteria during the Multi-criteria analysis

	Performance Criteria	Weighting
Feasibility 50%	Indicative Cost	25%
	Spatial requirements	20%
	Maintenance Requirements	20%
	Regulatory and Public Acceptability	10%
	Flexibility and scalability	25%
Sustainability 50%	Carbon intensity	20%
	Blue-green space provided	30%
	Climate Resilience	30%
	Surface water quality	20%

6.3 Stormwater Management Options

6.3.1.1 Across the Opportunity Areas, it is essential that a cohesive and integrated approach is adopted to effectively manage surface water quality and quantity from source generation to ultimate discharge, including the following aspects:

- Plot and development scale source-control measures, to control the quality and quantity of surface water runoff generated on site. This will prevent inundation of strategic surface water conveyance networks and facilitate the management of water quality throughout the surface water treatment train.
- A streetscape surface water drainage network for conveyance of runoff from source to ultimate discharge, while providing attenuation and water quality treatment.
- Ultimate discharge of runoff (either to sewers, surface waterways or recycled end use).

6.3.1.2 Within the stormwater management strategy, attenuation storage must be provided in order to achieve Greenfield runoff rates, which is central to the viability and vision of the overall development. A number of approaches have been highlighted to achieve this, including:

- Green, surface source control measures, including permeable surfacing, bio-retention, swales and surface water storages;
- Green roofs;
- Storage provided within the strategic SuDS network; Underground attenuation tanks;
- Downstream above ground stormwater retention

6.3.1.3 The results of the MCA for these measures is shown in Table 6-3 and Table 6-4 and described in the following sections.

6.3.2 New Build Areas

6.3.2.1 For the new build areas within Old Oak Common and Park Royal, the MCA indicates a preferential hierarchy of measures to achieve the required storage, as described:

1) Green Roofs have been assessed as the most preferential means of providing attenuation, due to their limited spatial requirements and the potential to provide multiple benefits for attenuation, water quality, amenity and green space. Preliminary calculations indicate that these have the potential to provide up to 20% of required attenuation (which could be improved through the incorporation of integrated water storage). These features should be maximised on all development sites.

2) Following this, on-plot green source control measures such as green walls, bio retention systems, swales and surface ponds have been assessed as the next most preferential means of providing attenuation and should be maximised on all sites. Additionally, permeability should be maximised wherever possible, with a minimum recommendation of 40% of ground level permeability, preferably through vegetated surfacing.

3) The delivery of a strategic surface water drainage network will additionally provide a variable volume of attenuation, (up to 20%, depending on scale and extent); although it is emphasised that capacity must be sufficient for streetscape drainage and conveyance of residual flows from plot to any downstream storages.

6.3.2.2 Each of these measures should be maximised as far as possible within the Opportunity Areas, as reflected in the Scenario summary presented in Table 6-1 above. However, due to the spatial constraints of the development and the significant attenuation volumes required, these measures will be insufficient to achieve the desired volumes. As such, residual storage would need to be provided through either:

4) Strategically dispersed above ground storages, linked to the surface water network, wherever spatially feasible (scenarios 2, 4 and 6).

5) Residual storage provided using underground attenuation tanks, preferably installed within the development plots (scenarios 1, 3, 5).

6.3.2.3 In general, below ground storage is considered the least preferable option for providing storage as opposed to the other blue-green infrastructure solutions discussed, due to the limited additional benefit and from competing pressures for underground space from other subterranean uses. For this reason, Scenarios 2, 4 and 6, presented in Table 6-1 are deemed to be more preferable than Scenarios 1, 3 and 5.

6.3.2.4 However, it is acknowledged that below ground storage may be the most practical means of achieving (at least some of) the required attenuation volumes, particularly within development plots, which are likely to be extremely spatially constrained. This provision of sufficient storage within plots is required in order to manage water quality and avoid inundation of downstream conveyance networks.

6.3.2.5 Conversely, above ground storages are likely to be more practical when provided downstream of the plots, within areas of the public realm or open green space, such as for example, Wormwood Scrubs.

6.3.2.6 Therefore, a balance of on-plot to downstream storage is required, reflecting the desirability to manage surface water at the surface wherever possible, whilst recognising the spatial constraints of the development proposals.

6.3.2.7 The location and provision of attenuation storages will need to be carefully designed in conjunction with the strategic conveyance network, and will be strongly influenced by the natural hydrological catchments and stormwater discharge location. It will also be important to consider where ponding of surface water occurs naturally as indicated in the high risk flood areas (see section 3.4). There is opportunity to work with the natural flow of surface water to promote above ground storage in locations within the masterplan to alleviate surface water flood risk. There are several options available for discharge of the collected, attenuated, treated and conveyed stormwater, including:

- Discharge to the combined Counters Creek sewer system;
- Discharge to the Grand Union Canal;
- Discharge to the Mogden surface water catchment;
- Direct discharge to the River Brent;
- Discharge to an underground aquifer for groundwater recharge;
- Harvesting and reuse for recycling, as discussed below

6.3.2.8 In line with the sustainable drainage hierarchy, recycling of surface water (as discussed below) or discharge to surface water bodies is considered to be preferable. The Grand Union Canal, in particular, is likely to present a beneficial discharge option; however, greater hydrological information, consultation and analysis would be required to confirm suitability.

6.3.3 Retained Areas

6.3.3.1 Within the retained areas of Park Royal, the same preferential hierarchy of attenuation options is highlighted. However, it is recognised that retrofit may be more reliant on opportunities arising through the incremental renovation and redevelopment across the area.

6.3.3.2 It is recommended that targeted and opportunistic SuDS retrofits are undertaken within properties, particularly including retrofit of green roofs and blue-green infrastructure. Similarly, retrofit of SUDS should be undertaken within the existing streetscape wherever spatially possible, aiming to remove and attenuate as much surface water as possible from the combined sewage system. In particularly, water management infrastructure should be integrated within delivery of newly planned green space and planned streetscape regeneration. The high risk flood areas indicated in Section 3.4 of this report indicate areas where SuDS systems could retrofitted to manage flows of water as well as provide attenuation.

6.3.3.3 Within all redevelopments and property refurbishments, attenuation storage to achieve Greenfield rates should be achieved, with a preference for green, surface SuDS measures. Similarly, incrementally extended/altered plots should be preferentially discharged to the Grand Union Canal or River Brent, provided there is appropriate management of water quality and quantity for this to be achieved without exacerbating flood risk or resulting in detriment to waterway health.

Table 6-3: Multi-criteria analysis summary for stormwater management measures in new build areas. The defined weightings have been applied to the score for each criterion to indicate a cumulative score and comparative measure ranking.

Criteria		Downstream Surface Attenuation	SuDS Source Control	Green Roofs	Underground Attenuation	Strategic SuDS Networks
Deliverability	*Capital Cost*	✓✓✓	✓✓✓	✓✓	✓✓✓	✓✓✓
	Operational and maintenance requirements	✓	✓	✓	✓	✓
	Space Requirements		✓	✓✓✓	✓✓✓	✓
	Regulatory and Acceptability Challenges	✓✓	✓✓	✓✓	✓✓	✓✓
	Flexibility and scalability	✓✓	✓✓✓	✓✓✓	✓✓	✓✓
Sustainability	*Carbon Intensity*	✓✓	✓✓	✓✓	✓✓	✓✓
	Blue-green space provided	✓✓✓	✓✓✓	✓✓✓		✓✓✓
	Climate Resilience	✓✓	✓✓	✓✓	✓✓	✓✓
	Surface water quality	✓✓	✓✓✓	✓✓✓	✓✓	✓✓✓
Measure Ranking		4	2	1	5	3

KEY

✓✓✓	High benefit
✓✓	Medium benefit
✓	Low benefit
	No benefit

Table 6-4: Multi-criteria analysis summary for stormwater management measures in retained areas. The defined weightings have been applied to the score for each criterion to indicate a cumulative score and comparative measure ranking.

Criteria		Downstream Surface Attenuation	SuDS Source Control	Green Roofs	Underground Attenuation	Strategic SuDS Networks
Deliverability	*Capital Cost*					
	Operational and maintenance requirements	✓✓	✓✓	✓✓	✓✓	✓✓
	Space Requirements		✓	✓✓✓	✓✓✓	✓
	Regulatory and Acceptability Challenges	✓✓	✓✓	✓✓	✓✓	✓✓
	Flexibility and scalability	✓✓	✓✓✓	✓✓✓	✓✓	✓✓
Sustainability	*Carbon Intensity*	✓✓	✓✓	✓✓	✓✓	✓✓
	Blue-green space provided	✓✓✓	✓✓✓	✓✓✓		✓✓✓
	Climate Resilience	✓✓	✓✓	✓✓	✓✓	✓✓
	Surface water quality	✓✓	✓✓✓	✓✓✓	✓	✓✓✓
Measure Ranking		4	2	1	5	3

KEY

✓✓✓	High benefit
✓✓	Medium benefit
✓	Low benefit
	No benefit

6.4 Recycling Options

6.4.1.1 The installation of a strategic non-potable water recycling solution for the development areas is essential to offset potable demand and reduce discharges. As illustrated in the water balance section of this report, it has been estimated that non-potable water recycling can achieve a minimum expected reduction in water demand of approximately 20%, with greater savings possible through outdoor use of water for public irrigation, as well as use to meet specific commercial and industrial process demands.

6.4.1.2 Additionally, potable reuse of reclaimed water supplies is being increasingly considered globally, with ongoing technological advancement in water treatment, allowing for greater water quality outcomes and mitigation of risk. Given the significant timescales proposed for the development, it is anticipated there will have been significant advances in this area, stimulated by increasing global awareness of climate change and resource shortage. Furthermore, de-regulation and increased public awareness of water supply issues are anticipated to create a more favourable climate for delivery. Therefore, flexibility for future potable use of recycled water supplies should additionally be built into the overall water management strategy for the Opportunity Areas.

6.4.1.3 The various options for water recycling have been assessed using a multi-criteria analysis, highlighting the varied benefits and costs associated with each option. The outcomes of this MCA are shown in Table 6-5 and described below.

6.4.2 New Build Areas

6.4.2.1 Several options for water recycling are present, and could be harnessed to effectively augment centralised water supplies. These are described in order of assessed preference below:

1) *Wastewater Recycling for non-potable use (Scenarios 3 and 4)*

This has been selected as the preferential option for delivering a strategic non-potable solution. Compared to stormwater recycling, wastewater recycling has a higher climate resilience and associated certainty of supply. This is also likely to present less spatial challenges, with a smaller anticipated spatial footprint, lower required water storage, and less reliance on overland hydrological connectivity. Furthermore, a range of innovative systems are entering the market, providing designs which are increasingly compact, scalable, sustainable and able to be aesthetically integrated within the urban form.

Importantly, wastewater recycling is also considered to allow for a greater degree of flexibility in implementation, as the greater volume of available flows means that a recycled supply could be used to offset potable demands to a more substantial degree, if consideration of appropriate non-potable end uses is expanded (for example including laundry use), or if future technological and socio-institutional advancement allows for potable use of recycled supplies. Additionally, utilising wastewater for non-potable supplies conserves an opportunity to utilise higher raw quality rainwater supplies for potable use (e.g. from rainwater harvesting from clean roofs). Therefore, if appropriately delivered, investing in the initial infrastructure for wastewater collection, treatment and redistribution may allow greater flexibility for increased future use.

2) *Stormwater Recycling (Scenarios 5 and 6)*

Stormwater recycling is indicated to be an alternative approach to providing a network-based non-potable supply solution. However, climate dependence is a primary disadvantage of this as a supply option, with the requirement for significant balancing storages to manage seasonal fluctuation, and back up centralised supplies for dry years. Additionally, more detailed assessment and modelling is required to confirm the feasibility of this option, to gain greater certainty into the expected flows, and the ability to convey surface flows across the different areas of the development (given the presence of significant constraining infrastructure) which may limit the effective catchment area.

Additionally, currently the extent to which centralised water demand can be offset is limited by the non-potable demand. However, in the event that future potable use is considered, then this will become limited by the availability of potable supplies. In this scenario, stormwater recycling will have limited capacity to support wider uses within the development.

3) *Greywater Recycling (Scenarios 1 and 2)*

Greywater recycling is indicated to be the least preferable option for non-potable reuse within the development. This is because the preliminary costing undertaken indicates that there are capital and operational efficiencies to be gained by delivery of a more centralised, network based solution to recycling. This is also likely to be more energy efficient than operation of a number of isolated, plot scale recycling options.

However, greywater nonetheless presents a highly beneficial option to effectively managing water supplies within the Opportunity Areas. Furthermore, it is recognised that there are a number of challenges inherent in the achieving the delivery and ongoing operation of a third pipe network. If this becomes infeasible, then greywater provides an advantageous plot-based solution to water recycling.

6.4.2.2 Roofwater recycling has not been included as an individual recycling option in the MCA as it does not meet the core project objectives. This is because the limited rooftop catchments will not provide sufficient flows to meet the non-potable demand within the high density development. Roofwater imported from large rooftop catchments within Park Royal could be collected centrally and utilised to meet this demand; however, this would require complex retrofit of pipework, with associated cost and feasibility considerations, and is considered to provide limited additional benefit over stormwater recycling.

6.4.2.3 However, if potable water recycling is considered in the short term, roof water presents a particular opportunity, as a source with particularly high quality. Allowance for potable augmentation would mean that harvested water could be collected, treated and directly mixed with centralised supplies, avoiding the difficulties associated with piping supplies across the catchment boundaries. If considered, it is recommended that stringent water quality monitoring be implemented, over a validation period, during which water supplies could initially be utilised for non-potable use. Following validation, water could be directly supplied to the potable network. This would be delivered in combination with a non-potable wastewater recycling system for optimal benefit. New build properties in Park Royal may provide particular opportunities for the delivery of pilot systems (due to more favourable catchment and demand characteristics).

6.4.2.4 Whilst a preferred option has been suggested, it should not be assumed that only a single, unique approach to recycling should be implemented. A variety of stormwater conveyance and storage infrastructure will be required across the development, which may be harnessed to provide more appropriate localised opportunities for green space irrigation, with lower required water treatment, and therefore a lower cost of supply. Similarly, plot-scale greywater and rainwater (or combined greywater rand rainwater) recycling may be appropriate for properties where connection to a distribution network is not feasible or advantageous. In the long term, the overall objective should be to provide a diverse portfolio of fit-for-purpose centralised and decentralised supply solutions, allowing greater operational flexibility and system resilience.

6.4.3 Retained Areas

6.4.3.1 Within existing areas of Park Royal, retrofit of dedicated non-potable internal distribution pipework is unlikely to be feasible, which will limit the applicability of most recycling options. However, retrofit of rainwater harvesting systems is likely to be feasible at several properties, due to large available roof catchments, and the likelihood of specific, high demand water uses which could be met with non-potable supplies. In order to maximise benefit, this is likely to require a targeted approach to retrofit, based on the individual water use characteristics. Additionally, as regeneration of the area is gradually stimulated, all new properties should be installed with an alternative means of water supply. This may be through connection to an adjacent non-potable network, if feasible, or through delivery of a localised rainwater or greywater supply (depending on the flow characteristics of the property).

Table 6-5: Multi-criteria analysis summary for water recycling measures in new build areas. The defined weightings have been applied to the score for each criterion to indicate a cumulative score and comparative measure ranking.

Criteria		Stormwater Harvesting for non-potable re-use	Wastewater Recycling for non-potable reuse	Greywater Recycling for non-potable reuse
Deliverability	*Capital Cost*	✓✓	✓✓✓	✓
	Operational and maintenance requirements	✓	✓	
	Space Requirements		✓✓	✓✓
	Regulatory challenges and Public Acceptance	✓	✓	✓
	Flexibility and scalability	✓	✓✓	✓✓✓
Sustainability	*Blue-green space provided*	✓✓✓	✓	
	Carbon intensity	✓	✓	✓
	Climate Resilience	✓	✓✓✓	✓✓✓
	Surface water quality	✓✓✓	✓✓	✓
Measure Ranking		2	1	3

KEY

✓✓✓	High benefit
✓✓	Medium benefit
✓	Low benefit
	No benefit

6.5 Scenario Comparison

6.5.1.1 The key available options for water management are primarily associated with the new build areas, relating to the primary recycling option to be implemented (wastewater, stormwater or greywater) and the balance of residual attenuation storage provided (on-plot underground attenuation or downstream above ground storage), reflecting the six key scenarios presented in Table 6-1.

6.5.1.2 These aspects are also interdependent. For storm water recycling, greater capacity of the conveyance network would be required, given the requirement for all flow to be centrally collected for re-use and a greater volume of downstream surface attenuation would be provided. Wastewater and greywater recycling are, however, less dependent on the surface water network, allowing dispersed disposal to waterways, sewers or for localised reuse.

6.5.1.3 A summary description of each of the six scenarios is provided in Table 6-6 below, including the advantages and disadvantages of each. Although the type and extent of infrastructure measures to deliver the key objectives varies within each scenario, there are common water management options which make up the base of all scenarios. These common features are:

- Achieving the highest standards of water demand management, through installation of high specification water efficient fixtures and fittings and use of smart network and metering technologies;
- Use of on plot source control SuDS measures such as green roofs on buildings.
- Management of storm water runoff within a connected network of strategic streetscape SuDS located at public open areas, streets and roads.

6.5.1.4 Conceptual diagrams of options 2, 4 and 6 are also presented in Figure 6-1 to Figure 6-3 for illustrative purposes (it should be noted that the spatial configurations indicated have not been confirmed in these figures).

6.5.1.5 Preferred solution

6.5.1.6 The identification of six potential option strategies provides a degree of flexibility for the overall Strategy prior to developing a preferred solution in detail. However, using the outcomes from the MCA process, it is possible to highlight the currently preferred solution based on the score against the Strategy's key performance indicators.

6.5.1.7 The MCA scoring has indicated a preference towards above ground attenuation of stormwater wherever possible due to the significant potential for the creation of multi-functional, multi-beneficial open space and the greater scope for flexibility around where attenuated water could eventually be discharged. It would allow options for the use of the River Brent or the GUC to be used for additional storage where feasible. This option also allows for cost efficiencies (both build costs and operational costs) through the provision of strategic storage solutions and SuDS networks.

6.5.1.8 The MCA also demonstrated a preference for wastewater recycling as a strategic water reuse solution for non-potable demand. Compared to the site based greywater recycling option, wastewater recycling provides both build and operational cost efficiencies through provision of area-wide strategic infrastructure such as a centralised treatment facility and area-wide piped network distribution system. It also provides a more climate resilient source of non-potable supply as wastewater generation is relatively constant through the year compared to reliance on storm water recycling. Lastly, it provides flexibility for storm water to be used in the future for other noon-potable uses within the home, or even potable use from clean sources such as roof runoff.

6.5.1.9 Scenario 4 combines these preferred storm water management and water re-use options and is therefore indicated to be the preferred Scenario. Section 0 sets out in more detail the key features of the preferred strategy option.

Table 6-6: Summary of strategy scenarios, including pros and cons

Scenario	Scenario Description	Advantages	Disadvantages	Summary
1	Residual storm water runoff is managed by a mixture of some above ground SuDS attenuation storage and use of underground tanks provided at site level. To reduce overall demand further, all non-potable demand for new development is met through greywater recycling units provided at site level.	✓ No strategic scale infrastructure required – ease of deliverability and phasing. ✓ Climate resilient supply of recycled water for non-potable demand. ✓ Future flexibility for use of storm water for other non-potable or potable demands.	× Minimal provision of multi-beneficial open spaces × Less efficient in terms of build and operational costs for both storm water management and water reuse elements	This scenario focuses on ease of deliverability but is less cost efficient and also provides less opportunity for the creation of multi-beneficial space
2	Residual storm water runoff is managed largely using above ground attenuation storage areas which are either dispersed through strategic available space within the opportunity areas and/or at a centralised storage location (to be identified); minimal storage is provided by underground attenuation tanks. As with scenario 1, to reduce overall demand, all non-potable demand for new development is met through greywater recycling units provided at site level.	✓ Creates opportunity for multi-functional open space through provision of surface water SuDS. ✓ Climate resilient supply of re-cycled water for non-potable demand. ✓ More straightforward delivery of on-site water re-use option. ✓ Future flexibility for use of storm water for other non-potable or potable demands. ✓ More efficient in terms of build and operational costs for area-wide storm water management option.	× Significant amount of open space required to deliver preferred storm water management × More challenging delivery of strategic storm water management which could affect phasing × Less efficient in terms of build and operational costs for water re-use option	This scenario balances deliverability against cost efficiency, and also provide multi-beneficial above ground water storage measures.
3	As with Scenario 1, residual storm water runoff is managed by a mixture of some above ground SuDS attenuation storage and significant use of underground tanks provided at site level. To reduce overall demand, all non-potable demand for new development is met through recycling of wastewater from development at a central treatment unit and provided to buildings through a dedicated area-wide pipe distribution network.	✓ More straightforward delivery of on-site storm water management option ✓ Climate resilient supply of re-cycled water for non-potable demand. ✓ Future flexibility for use of storm water for other non-potable or potable demands. ✓ More efficient in terms of build and operational costs for area-wide re-use management option.	× Minimal provision of multi-beneficial open spaces × More challenging delivery of strategic re-use option which could affect phasing × More intensive treatment required for re-use stream of water	This scenario balances deliverability against cost efficiency, but provides less opportunity for the creation of multi-beneficial space.

Scenario	Scenario Description	Advantages	Disadvantages	Summary
4	As with Scenario 2, residual storm water runoff is managed largely using above ground attenuation storage areas which are either dispersed through strategic available space within the opportunity areas and/or at a centralised storage location; minimal storage is provided by underground attenuation tanks. As with scenario 3, to reduce overall demand, all non-potable demand for new development is met through greywater recycling units provided at site level.	✓ Creates opportunity for multi-functional open space through provision of surface water SuDS. ✓ Climate resilient supply of re-cycled water for non-potable demand. ✓ Future flexibility for use of storm water for other non-potable or potable demands. ✓ More efficient in terms of build and operational costs for area-wide storm water and water re-use management option.	× Significant amount of open space required to deliver preferred storm water management × More challenging delivery of strategic storm water management and re-use option which could affect phasing	This scenario maximises cost efficiency, provision of multi-beneficial above ground water storage measures, and a more resilient non-potable demand source, but is a challenging scenario to deliver in terms of phasing.
5	As with Scenarios 1 and 3, residual storm water runoff is managed by a mixture of some above ground SuDS attenuation storage and significant use of underground tanks provided at site level. To reduce overall demand, all non-potable demand for new development is met through recycling of wastewater from development at a central treatment unit and provided to buildings through a dedicated area-wide pipe distribution network.	✓ More straightforward delivery of on-site storm water management option ✓ More efficient in terms of build and operational costs for area-wide re-use management option.	× Minimal provision of multi-beneficial open spaces × More challenging delivery of strategic re-use option which could affect phasing × Less climate resilient water re-use option × Less flexibility for future use of storm water for other non-potable (or potential potable) uses	This this scenario balances deliverability against cost efficiency, but provides less opportunity for the creation of multi-beneficial space, and a less reliable all year-round supply of non-potable water
6	As with Scenario 2 and 4, residual storm water runoff is managed largely using above ground attenuation storage areas which are either dispersed through strategic available space within the opportunity areas and/or at a centralised storage location; minimal storage is provided by underground attenuation tanks. As with scenario 5, to reduce overall demand, all non-potable demand for new development is met through recycling of storm water from development at a central treatment unit and provided to buildings through a dedicated area-wide pipe distribution network.	✓ Creates opportunity for multi-functional open space through provision of surface water SuDS. ✓ More efficient in terms of build and operational costs for area-wide re-use management option.	× More challenging delivery of strategic storm water management and re-use option which could affect phasing × Less climate resilient water re-use option × Less flexibility for future use of storm water for other non-potable (or potential potable) uses	This scenario maximises cost efficiency, and provision of multi-beneficial above ground water storage measures, but is a challenging scenario to deliver in terms of phasing and offers less resilience to drought conditions and dry periods.

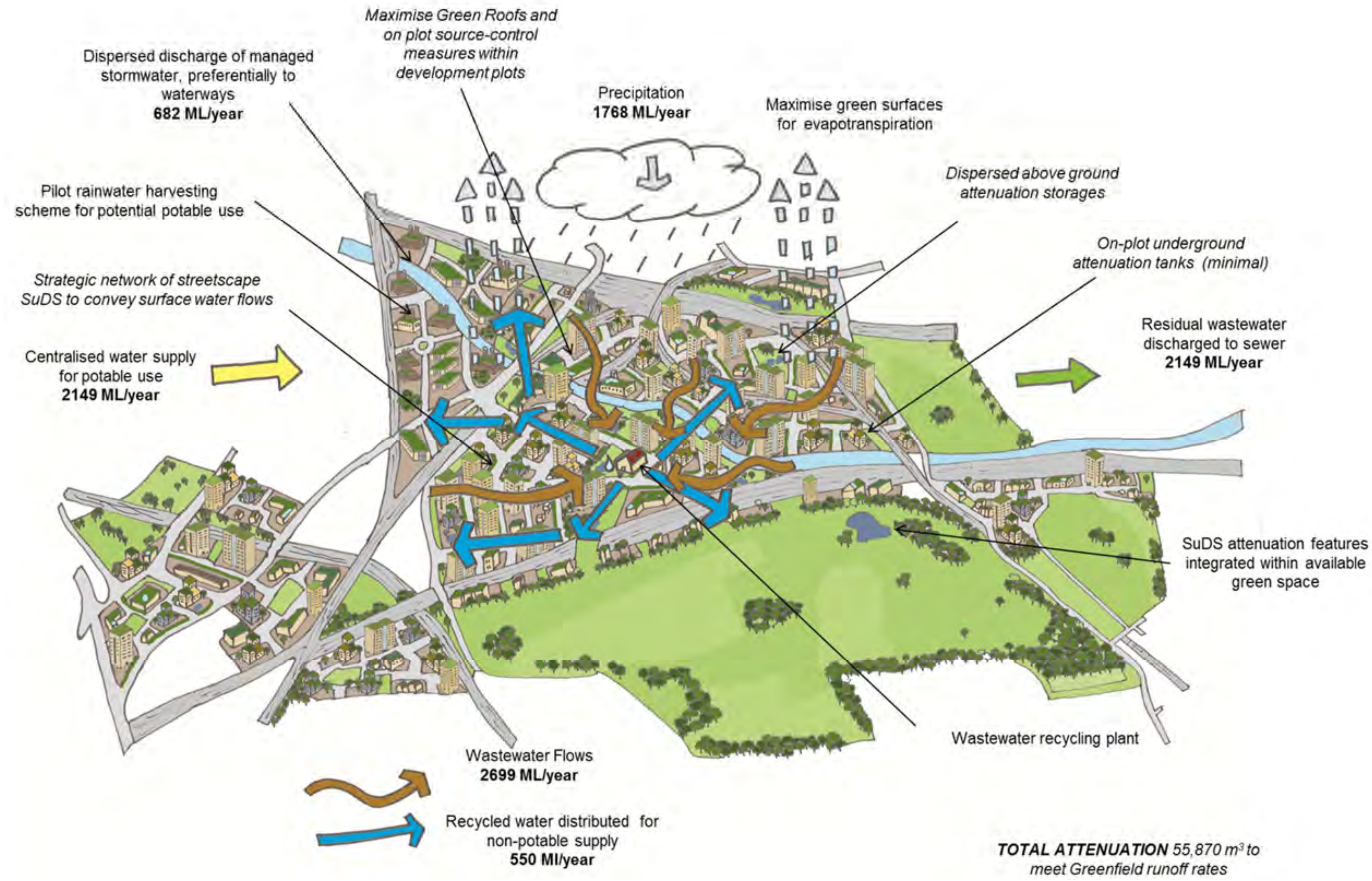


Figure 6-1 - Scenario 4 - Wastewater Recycling

6.5.1.10 Figure 6-1 illustrates Scenario 4, which has been selected as the preferred approach to integrated water management across the development areas. In this scenario storm water runoff is treated and managed via attenuation, which is preferentially provided through on-plot and above ground blue green infrastructure, in line with the hierarchy specified in Section 6.3.2, with preferential discharge of managed stormwater to local waterbodies. To reduce overall demand, all non-potable demand is met through wastewater recycling, with a single centralised treatment facility and an area-wide third pipe network to provide non-potable water to new build areas. Further benefit may be provided through the installation of a pilot potable rainwater harvesting facility.

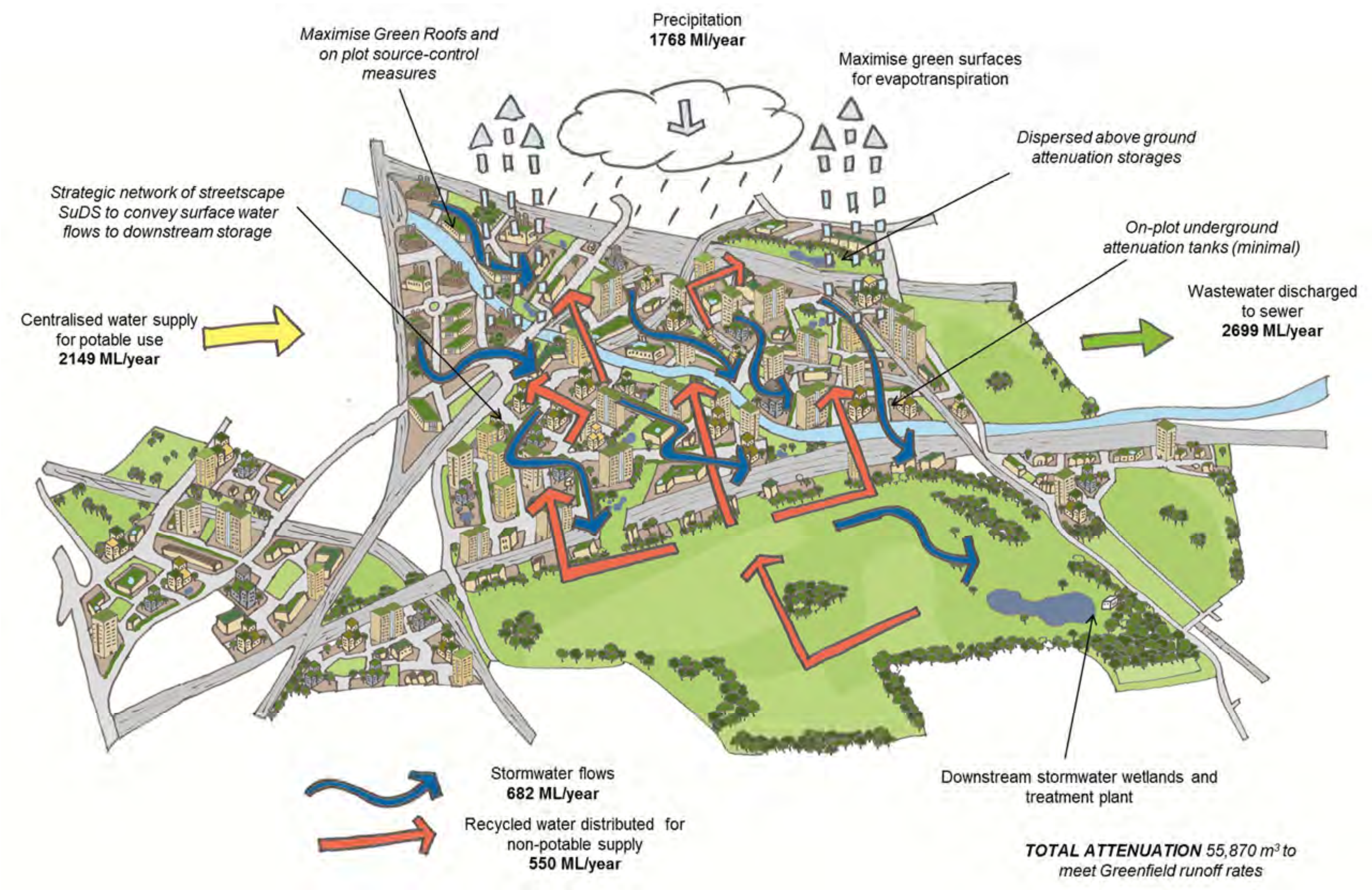


Figure 6-2 - Scenario 6 - Stormwater Recycling

6.5.1.11 Figure 6-2 illustrates Scenario 6, which is an alternative approach to water management through the development. Storm water runoff is treated and managed via attenuation, which is preferentially provided through on plot and above ground blue-green infrastructure, in line with the hierarchy specified in Section 6.2.1. Collected, treated stormwater is used to offset potable demand across the development, with a centralised collection and treatment facility and an area-wide third pipe network to provide non-potable water to new build areas.

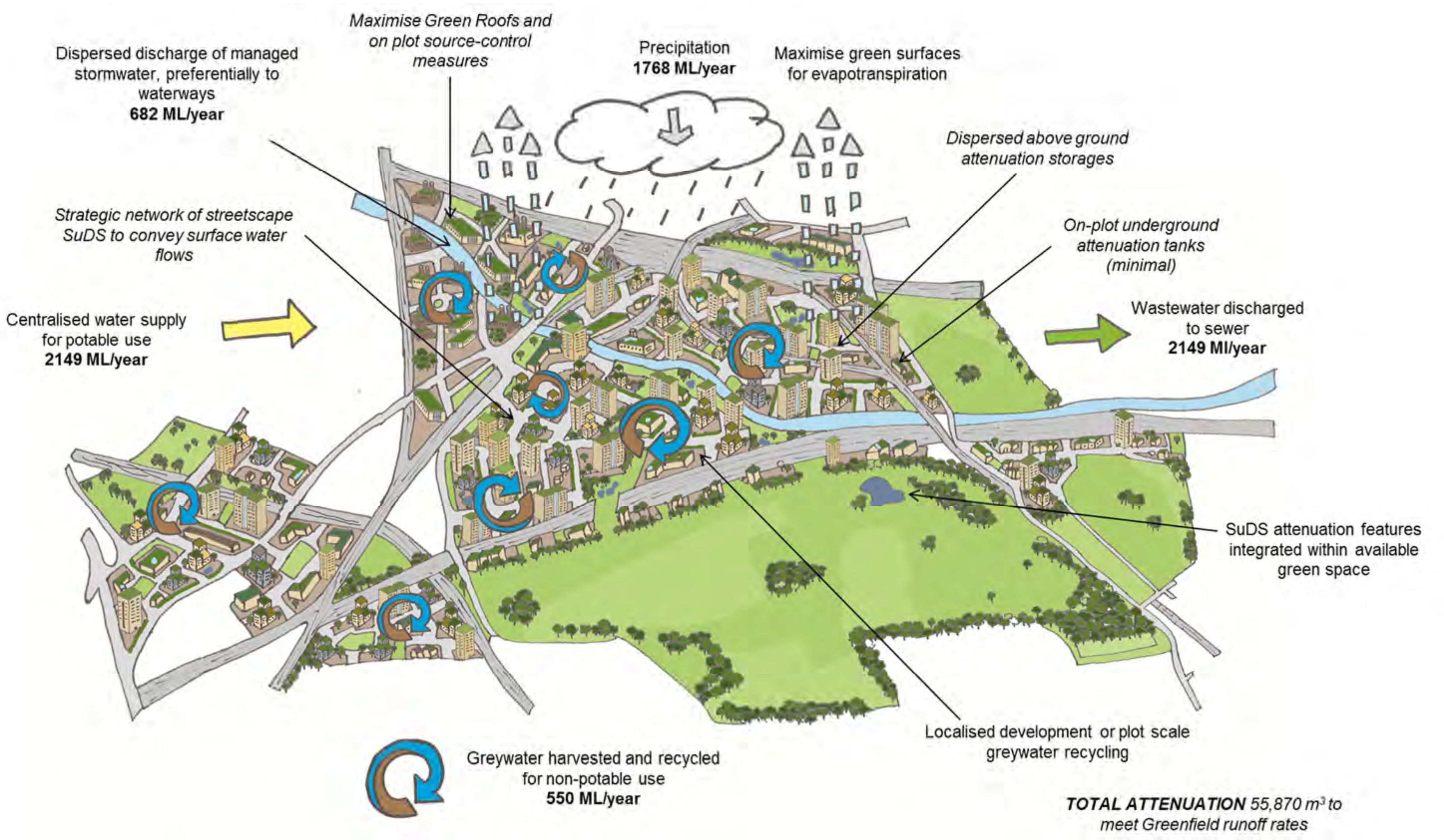


Figure 6-3 - Scenario 2 - Greywater Recycling

Figure 6-3 illustrates Scenario 2, which is an alternative approach to integrated water management across the development areas. Storm water runoff is treated and managed via attenuation, which is preferentially provided through on plot and above ground blue-green infrastructure, in line with the hierarchy specified in Section 6.2.1, and preferentially discharged to local waterbodies. To reduce overall demand, all non-potable demand is met through greywater recycling units, provided at a plot scale.

7 Strategy Overview

7.1.1.1 The preferred approach to integrated water management across the development site is conceptually illustrated in Figure 6-1. The key elements of this water management strategy are broadly summarised in Table 7-1 below:

Table 7-1 - Summary of preferred framework for Integrated Water Management across the Opportunity Areas

	Strategy Element	Old Oak Common and New Build Park Royal	Park Royal - Existing
Demand Management	Demand management and water efficiency	• All properties constructed to the maximum possible standards in water and energy efficiency. • Delivery of smart water supply network solutions with real time monitoring of water use and quality. • Delivery of educational opportunities integrated within the development.	• Targeted water efficiency retrofits and process improvements. • Incentive schemes to encourage property owners to undertake retrofit. • All new build developments and refurbishments to achieve maximum possible levels of water efficiency.
Surface Water Management	Plot and development scale source-control measures, to control the quality and quantity of surface water runoff generated on site	• Accessible, intensive green or blue-green roofs installed on all new buildings. • Maximise permeable surfacing within all development plots and installation of green SuDS systems, including bio-retention systems, retention ponds, swales, green walls and facades to maximise surface storage and treatment of runoff.	• Targeted and opportunistic SuDS retrofitting within existing properties, particularly including retrofit of green roofs and blue-green infrastructure. • All new build developments and refurbishments to include attenuation to achieve Greenfield rates, with a preference for green SuDS measures.
	A streetscape surface water drainage network for conveyance of runoff	• Strategic interconnected network of roadside swales and green infrastructure to drain roads and public spaces; conveying, attenuating and filtering storm water flows along the natural catchment hydrology.	• Retrofit of sustainable drainage systems within the streetscape wherever spatially possible, aiming to remove and attenuate as much surface water as possible from the combined sewer system. • Integrating water management infrastructure within delivery of newly planned green space and planned streetscape regeneration (including the planned enhancement of the Park Royal Centre).
	An attenuation storage strategy, providing attenuation to achieve Greenfield Rates	Provision of required storage in line with the following preferential sequence: • Maximise storage provision within blue-green roofs, green source control measures and streetscape SuDS network. • Remaining attenuation volumes to be provided in strategically dispersed offsite above ground storages where spatially feasible, in areas of open green space or public realm. • Residual volumes to be provided using underground attenuation tanks.	• Opportunistic and targeted retrofit of on-plot attenuation wherever spatially possible. • Investigate land acquisition for strategic network storage options, linked to delivery of streetscape SuDS retrofits. • All new build developments to achieve Greenfield discharge rates, with a preference for this to be achieved using above ground, green SuDS measures.
	Discharge of runoff	• Appropriately attenuated and treated water should be preferentially discharged to existing surface water bodies, including the Grand Union Canal. Further work and consultation will be required to confirm whether this is feasible without resulting in additional flood risk, and to confirm appropriate rates of discharge.	• Newly developed plots should be preferentially discharged to the Grand Union Canal or River Brent, provided there is appropriate management of water quality and quantity for this to be achieved without exacerbating flood risk or resulting in detriment to waterway health. • Further investigate extension of Mogden surface water catchment to handle additional flows.
Water Recycling	Strategic non-potable water network	• Delivery of a non-potable distribution network, with all buildings to be connected through non-potable distribution pipework. • Installation of a dedicated wastewater recycling system with advanced water treatment and non-potable redistribution. If wastewater treatment is not deemed feasible, then installation of a strategic stormwater or greywater harvesting solution should be pursued.	• Targeted retrofit of roof water recycling schemes, particularly for properties with outdoor use or process demands (not requiring re-plumping of internal pipework). • All new properties connected to adjacent non-potable network, if feasible, or installed with an alternative means of water supply. Preferably, localised supplies should be delivered through rainwater harvesting (if catchment and flow characteristics are appropriate), otherwise localised greywater recycling should be utilised.
	Allowance for future implementation of potable water recycling	• Installation of a pilot potable rainwater harvesting system with ongoing water quality monitoring (initial non-potable use of harvested water may be beneficial during monitoring). • Capacity design of treatment plant such that future potable wastewater recycling may be implemented.	• Rainwater harvesting should be investigated for newly proposed development, likely to be particularly advantageous for industrial properties with large roof space and lower density of employees. This may present particular opportunities for localised, pilot potable roof water recycling systems.

8 IWM Strategy Delivery

8.1.1.1 This section of the report considers how the various options identified within the described strategy could be effectively procured, constructed and maintained, and which parties might be best placed to deliver these. In general, this should be arranged such that benefits are derived for the Old Oak and Park Royal Schemes in terms of:

- Satisfying planning and regulatory requirements;
- Optimising cost for the works;
- Certainty of delivery of required works to meet the overall programme; and
- Placing risk and associated responsibility with the party that is best placed to manage this effectively.

8.1.1.2 It is anticipated that the works will be carried out across a variety of scales, from plot, to sub-area (development scale) to area scale and that therefore the solutions for each of these will vary.

8.1.1.3 Additionally, there a variety of mechanisms whereby costs on a strategic scale for the entire development could be cross-charged to individual plot developers. However, this will be highly dependent on a large number of factors; particularly, the means by which infrastructure works of this nature are recovered from the private sector.

8.1.1.4 It is considered that ongoing discussions with the key regional stakeholders and individual developers is required in order to further confirm the most appropriate of these potential mechanisms and the detail. In particular, these discussions should involve:

- CIL and whether the works could be recovered through this in part;
- S106[8] / S278[9] etc. and how costs could be allocated to the plot developers;
- The charging mechanisms between Thames Water and the plot developers; and
- The use or otherwise of an ESCO (Energy Services Companies) and/or MUSCO (Multi Utility Services Companies) and how this would relate to costs paid by the plot developers.

8.1.1.5 The following sections summarise the key considerations which will need to be taken into account during the delivery of the works, and how delivery of the key components of the strategy might be approached.

8.2 Key Delivery Considerations

8.2.1.1 There are a number of criteria that will need to be considered in the delivery of various aspects of the strategy, recognising that this may be impacted on by the specific requirements of those organisations that will both carry out the works and be responsible for the ongoing operation and maintenance. The major factors that have been considered are described below.

8.2.2 Location

8.2.2.1 There are a number of proposed measures that involve works directly to or adjacent to proposed buildings, and which are self-contained within the various development plots. As such, these works would be carried out by the particular plot developers. There are, however, a number of solutions at both sub-area and area scale, which involve works outside of the plot boundaries. Therefore, these measures could conceivably be carried out by a number of parties..

[8] Town and Country Planning Act (1990)
[9] Highways Act (1980)

8.2.3 Scale of the works

8.2.3.1 The proposed solutions cover some very significant works and, as such, are likely to yield benefits to the wider Old Oak Common and Park Royal area, rather than being specific to an individual plot or development parcel. In this circumstance, it is likely that these works would be carried out by Thames Water or others, rather than by individual plot developers, as the need for them is strategic and could also require the use of statutory powers in terms of land acquisition, which they are best placed to deliver.

8.2.4 Timing of the works

8.2.4.1 Following on from the above, it is clear that there will be some works for which timing will be critical to serve the development, especially in the early phases. Where this is the case, a balance will be required between those works which are purely for the benefit of a single development, and therefore could be the responsibility of that plot developer, and those works which are required for the wider development, but again which need to be procured and delivered at an early stage. For the latter, this could represent a significant opportunity for Thames Water / others to deliver these works and then for the individual plot developers to connect to these systems.

8.2.5 Cash flow for the works

8.2.5.1 It is recognised that certain solutions will involve significant cost, and that these costs will have to be incurred at an early stage in the overall development. In these circumstances, consideration will be required as to which party is best placed to be responsible for these works. Given the level of cost, it is very unlikely that one or more of the plot developers would be in a position to fund this, in part or as a whole, as the impact on their cash flow and hence the viability of their developments would be significant. In these circumstances, it would be preferable if Thames Water or a third party procured and funded these works, while recognising that there may be cross-charging mechanisms to the plot developer(s).

8.2.6 Potential for integrated infrastructure delivery

8.2.6.1 The Old Oak Common and Park Royal Opportunity Areas will involve extensive infrastructure delivery, to support the proposed development. As such, there are likely to be efficiencies which may be realised through adopting a cohesive strategy for integrated delivery of new water infrastructure in conjunction with other utilities, public realm or transport infrastructure.

8.2.7 Overall duration of the works

8.2.7.1 There is recognition that the delivery of the Old Oak Common and Park Royal Opportunity could take place over 30 years and therefore this needs to be considered when identifying an optimal delivery strategy. Given these timescales, there is a need to maintain flexibility in the solutions that are developed, so that they may be able to respond to new Regulations, advancements in technology and changing market conditions over this period. As such, this long term approach and need to maintain flexibility could be more suited to Thames Water or other third parties, who are considered to be better placed to assess how this could impact on their approach to providing long-term solutions in the context of the wider network, rather than the plot Developers, who will be primarily concerned with solutions which meet the needs of their developments at the time when these are being delivered.

8.2.8 Appetite for taking on risk and responsibility for delivery of the works

8.2.8.1 This will have an impact on the delivery strategy; with a desire to place risk and responsibility with those parties who are best placed to manage this, but without this negatively impacting on the wider strategy for the delivery of Old Oak Common and Park Royal. As such, it is considered that the plot developers will be best placed to take on the risk and responsibility for those items which are critical to the delivery of their schemes and for which they have the ability to control the outcome. However, where there is a strategic solution which is for the benefit of the wider development and which requires a significant degree of control over the final outcome, then it's more likely that this will be best placed to be managed by Thames Water / others.

8.2.9 Nature of companies that can deliver the works

8.2.9.1 This will be a key aspect of the delivery strategy; recognising that the market is developing in terms of companies that have the ability to carry out strategic works of this nature, and that there are changing Regulations affecting the delivery of such works in the water market. The impact of this is that there will be significant interest from the market in respect of delivery and long-term management of assets for a project of this scale and importance, driven by the substantial revenue streams that will be available from a variety of end occupiers. There are a number of examples of major schemes that are being delivered currently through ESCO's and MUSCO's including Kings Cross in London. The potential for a scheme of this scale to attract interest from the market, allied with the changes in Regulations of the Water Market is anticipated to be substantial.

8.3 Potential delivery approaches

8.3.1.1 Taking in to account all of the above factors, consideration has been given to the proposed solutions and how their delivery could be approached. This has been broadly divided between the surface water management aspects of the strategy and the water recycling solutions, including wastewater, storm water and grey water, while recognising that some solutions will applicable across more than one of these options.

8.3.2 Surface water management

8.3.2.1 A number of measures are recommended for installation within individual development plots, including the installation of green roofs, permeable surfacing, bio-retention systems and below ground attenuation measures. Being within the development boundaries, these are recommended as being best placed to be carried out by the plot developers, in line with regional planning policy and guidance given by the Lead Local Authorities.

8.3.2.2 However, the broader-scale solutions, including the delivery of streetscape surface water networks and downstream stormwater detention features are likely to have more distributed benefit, and could be delivered through a range of parties.

8.3.3 Strategic surface water network and attenuation

8.3.3.1 It is considered that this infrastructure may be best placed to be carried out by the party responsible for the delivery of the primary and secondary highways networks across the wider development, with the drainage network forming an integral part of the overall streetscape. As such, delivery could be the responsibility of one or more plot developer(s), where they are carrying out such works under a S278 Agreement (which could be particularly relevant where these works are required to be delivered at an early stage to serve a particular development rather than the scheme as a whole), the Highways Authority or another third party who are carrying out these works.

8.3.3.2 However, with respect to future maintenance requirements, it is likely that this would be best placed to with the Highways Authority, who are generally responsible for adopting and maintaining all SuDS within the adopted public highway, even where these have been carried out by individual developer(s). The operation of installed SuDS systems will also impact upon downstream systems, including the Thames Water sewer network, stormwater harvesting systems or waterway discharge points. Therefore, such parties may also require varying levels of consultation or responsibility with regards to ongoing maintenance.

8.3.3.3 Considering downstream attenuation storages, is considered that these works would be best placed to be delivered by third parties and not by plot developers, as the works will be of a significant scale and will involve substantial land take which will not be feasible for plot developers to deliver.

8.3.3.4 However, where developers are utilising dispersed, downstream options of network attenuation to achieve Greenfield runoff rates (as opposed to on-plot solutions), it may also be reasonable for contribution to be made to the capital and operational costs of delivery.

8.3.4 Strategic Water Recycling Options

8.3.4.1 Of the recycling options considered, localised greywater or rainwater harvesting solutions are deemed to be best suited to be delivered directly by the plot developers, as a part of the development construction and delivery. Engagement of specialist third party manufacturers and operators is expected to be required, and consultation with the wider area stakeholders would be recommended in the design of any such scheme.

8.3.4.2 Area-scale solutions for strategic water recycling networks are likely be unfeasible for delivery and/or operation by plot developers. Potential developers and/or operators could include Thames Water, third party operators or a combination.

9 Conclusions and Recommendations

9.1.1.1 The proposed regeneration of the Opportunity Areas presents an opportunity to deliver a new paradigm of water management. Old Oak Common, in particular, presents the chance to deliver a new system, harnessing the latest technological advancements to deliver an aspirational water sensitive development, sustained by a flexible and resilient portfolio of water infrastructure. Across existing areas of Park Royal, the transition will be more gradual, focused on targeted retrofit and harnessing opportunities where available. It is also intended that the water management strategy for these areas is synergistic with the wider sustainability and community aspirations of the redevelopment, delivering a vibrant, liveable centre.

9.2 The Preferred Strategy

9.2.1.1 A MCA process using key performance indicators has been undertaken for potential combinations of water management measures to derive a number of water management strategy options that meet the three core water management objectives of:

- Providing attenuation and sustainable drainage features to achieve Greenfield runoff rates:
- Minimising demand on the centralised potable water supply as far as possible; and
- Achieving a neutral discharge position.

9.2.1.2 Six potential strategy options were developed; all of which meet the core water objectives and therefore would allow development to proceed. Whilst the detail of how these strategy options would be delivered would need to be worked up in the next stages of the study, the delivery of any one of these options would ensure that combined discharges to the sewer system would not be increased (and significantly decreased in more extreme rainfall events); and, demand would be minimised and Mayoral targets for water demand met (and exceeded in most locations).

9.2.1.3 Of the options proposed, a preferred water management strategy option was selected based on the scoring against the performance criteria and the flexibility of deliverability which it would provide. This preferred strategy includes:

- Maximising levels of water efficiency and demand management, through innovation and the delivery of new technologies, smart networks and community engagement.
- A cohesive, integrated approach to managing surface water quality and quantity across the development, focusing on the provision of green sustainable drainage infrastructure, delivered to maximise benefit for amenity and biodiversity. This includes a hierarchical approach to providing attenuation via source control on plot, strategic SuDS networks for the public realm, and the provision of the remaining attenuation through dispersed or centralised attenuation with water quality management to achieve Greenfield discharges for storm events up to the 1 in 100 (with an allowance for climate change).
- To reduce discharge volumes to the combined sewer, develop options to discharge as much attenuated surface water possible through alternative discharge such as controlled discharge to the Grand Union Canal.
- Delivery of a strategic wastewater recycling solution with a single treatment location, providing non-potable water to reduce overall demand from centralised supplies. It is recommended that a strategic network-based solution is developed to provide the recycled water for non-potable use. At this stage, recycled wastewater has been indicated as the most preferential option; however, reclaimed stormwater and greywater are also potentially advantageous alternative or complementary solutions.
- To move closer to a position of water neutrality, direct potable water recycling is also recommended for further investigation. This may include use of harvested rainwater to directly augment potable supplies, and maintaining design flexibility to allow for non-potable recycling infrastructure to be scaled up to potable recycling; when the technical and social environments are appropriate.

9.2.1.4 Whilst a preferred strategy has been proposed it is intended that the water management approach remains flexible and able to be adapted in line with the development proposals, technological advancement and the selected delivery strategy. This approach has fed into the development of the Local Plan with the six potential strategy options highlighted within the draft Plan alongside recommended water and flood risk policies to ensure the aims and direction of the strategy are embedded in the plan making process and the planning decision process.

9.3 Next Steps for Strategy Development

9.3.1.1 Following consultation on this Strategy as part of the wider Local Plan consultation for the Opportunity Area, further refinements will be made to the preferred water management strategy. These refinements will be a core part of the detailed further assessment of the feasibility and outline design of the preferred strategy and a detailed plan for how the strategy will be delivered. This further work will take place in 2016, alongside the developing utilities strategy and environmental standard setting for the Opportunity Area.

9.3.2 Recommendations for Further Assessment

9.3.2.1 The following actions are recommended for the next stage of the strategy development in order to progress with further refining, scoping and delivering this integrated water management strategy:

- Greater investigation of the hydrological character of the Grand Union Canal and River Brent and further engagement with key stakeholders in order to confirm the suitability of natural catchment discharge to these locations.
- Spatial planning to target beneficial locations for surface water attenuation and conveyance networks. Particularly, it is recommended that preliminary design of a streetscape surface water network be undertaken and any required refinements to the masterplan targeted in order to harness the natural area hydrology. Similarly, in order to achieve Greenfield run-off there will be a need to consider off-site attenuation in surrounding open spaces, such as Wormwood Scrubs. The draft Local Plan for the development is understood to seek stakeholders' views regarding preferential attenuation locations.
- Ongoing engagement with key stakeholders across the Opportunity Areas to confirm the preferred mechanism for delivery of the IWM strategy, including capital investment and ongoing operation and maintenance. This will be central to confirming the preferred water recycling and storage strategy.
- Further detailed scoping of each of the recycling options is required. In particular, spatial configurations should be confirmed as early as possible, so that potential constraints are managed through the master-planning process, and infrastructure delivery streamlined to maximise cost efficiency and feasibility.
- Consideration of opportunities to align infrastructure delivery with other significant utilities provision within the Opportunity Area.
- Initial discussions with potential third party service operators and manufacturers should be undertaken to further scope the potential for delivery of innovative technologies and involvement of new service operators.

9.3.2.2 To support the wider water management options, the Strategic Flood Risk Assessment has highlighted high risk areas where one or more sources of flooding represent a risk to development. To mitigate risk within these areas, recommendations are made on how to manage development in some locations, and opportunities to combine flood risk management options with the preferred water management measures have been highlighted to provide strategic water management. These recommendations are set out below:

- In managing residual risk from canal breach flooding, it is recommended that development in Old Oak Common is set back from the canal. This is in keeping with the current masterplan proposals to create a green corridor along the canal;

- Development in the north west of Park Royal should be set back from the River Brent edges to enable a range of additional flood risk management options for the wider Brent corridor;
- Re-configuration of areas of green space proposed within the early Old Oak Common masterplan should be considered to be located in areas of existing surface water ponding to act as areas of dispersed attenuation storage.
- LBHF has previously considered the feasibility of providing storm water attenuation within Wormwood Scrubs to reduce the risk of flooding to property and infrastructure to the south of the Scrubs within the Borough. This could be combined with storm water attenuation from the Opportunity Area to provide benefit both to the Opportunity Area and the wider drainage catchment to the south.
- A drainage study is being carried out by Thames Water in order to establish the flow characteristics and capacity in the river and drainage system for the River Brent. The study is being carried out on behalf of North Brent and Harrow Flood Stakeholders Group. This could identify opportunities to provide discharge for attenuated surface water from Park Royal that fall into the topographical catchment of the Brent, thereby reducing discharge to the Counters Creek catchment,.
- Thorough retrofit of the Park Royal section of the site, there are opportunities for Blue Corridors (via raised kerbs) particularly around the high risk areas and associated roads identified to the south of the canal within the current industrial areas.

APPENDIX A
West London Opportunity Area Water Demand Analysis

This Appendix sets out a summary of the calculations for water demand and wastewater generation from the combined proposed development for Opportunity Areas and major planning applications sharing the same drainage infrastructure as the Old Oak Common and Park Royal study area.

In order to better understand the likely water demand and wastewater increases as a result of development occurring, each Opportunity Area has been considered in detail, looking at development proposals as well as (where available) planning applications for specific developments.

In so doing, the likely distribution of development within the Opportunity Areas was established in relation to the drainage infrastructure, confirming the uses occurring within the drainage catchment. This is summarised in Table A1.

Table A1: Proposed development within each Opportunity Area

OA Name	New Homes - Minimum	Population	Employment Capacity
White City	6,000	12,600	10,000
Kensal Canalside	3,500	7,350	2,000
Wembley	0	0	1,600
Earls Court and West Kensington	7,500	15,750	9,500
Total other OAs	**17,000**	**35,700**	**23,100**
Old Oak & Park Royal	24,000	46,200	55,000
Total – all OAs	***41,000***	***81,900***	***78,100***
Old Oak and Park Royal (%)	58.5%	56.4%	70.4%

Based on the expected development, daily residential and employment demands and wastewater volumes have been estimated, indicating the additional pressure this development will place on the Counters Creek catchment. A series of assumptions have been made to calculate per day water demands and waste water for each development, these have been outlined in Table A2.

Table A2: Assumptions used to calculate per day water demands and wastewater generation[1]

	Type	Litres per person per day
Water Demands	Residential Potable	110.65
	Residential Non-Potable	20.60
	Employment Potable	19.53
	Employment Non-Potable	18.00
Sewer Discharges	Residential Grey	75.11
	Residential Black	56.14
	Employment Grey	7.34
	Employment Black	30.19

The day values have then been scaled up to give an annual overview of annual demand and wastewater generated within the Opportunity Areas, basing figures for residential development on 365 days and employment development on 253 days, allowing for the nature of use of employment uses. The results are shown in Table A3.

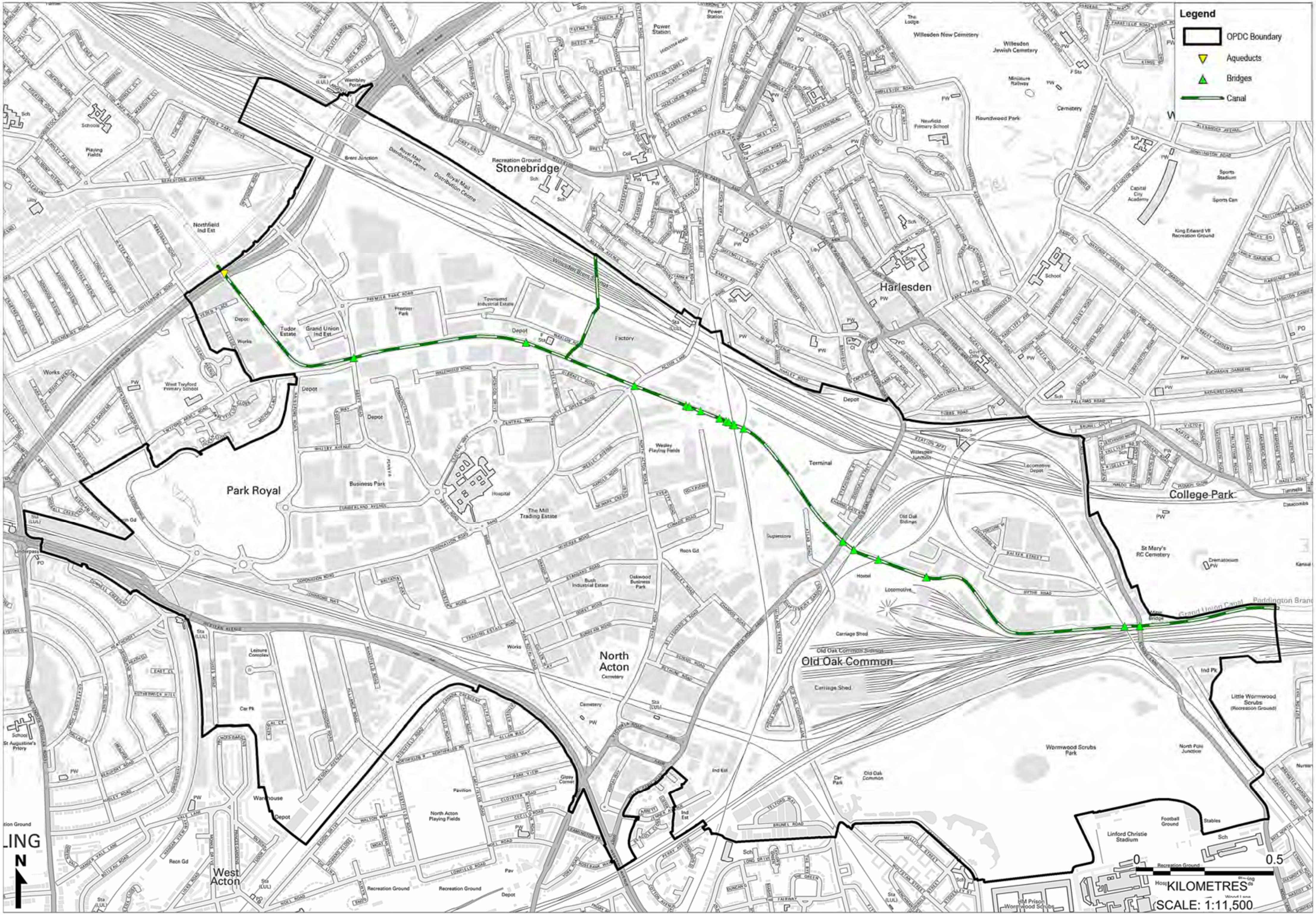
[1] These values have been estimated using the usage estimates and maximum fittings consumption, as per the Building Regulations (Approved Document G) and British Standard BS8542

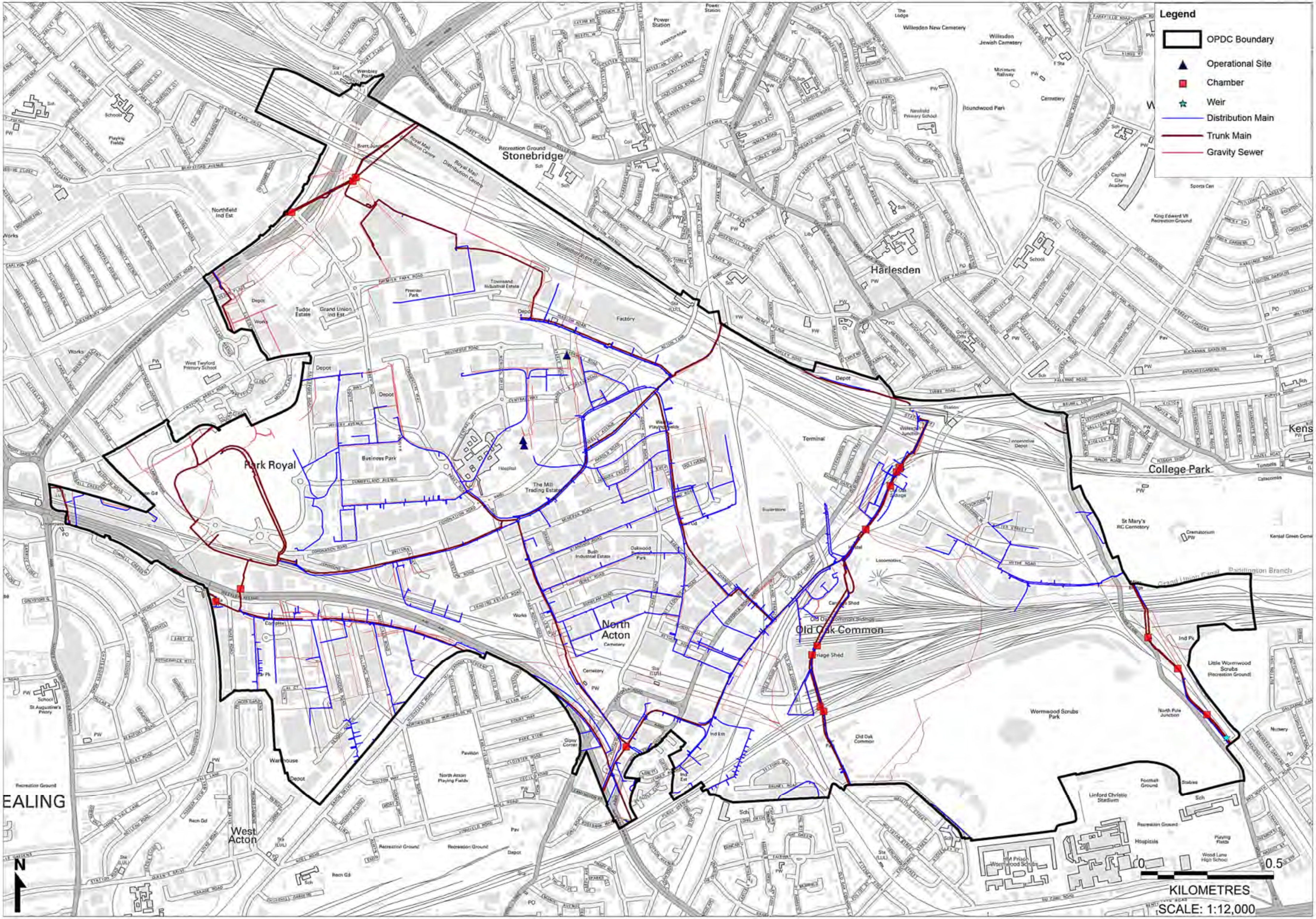
Table A3: Daily residential and employment demand within each Counters Creek Opportunity Area

OA Name	Annual residential demand (Ml/d)	Annual employment demand (Ml/d)	Annual residential waste (m^3/d)	Annual employment waste (m^3/d)
White City	1.65	0.38	1,654	375
Kensal Canalside	0.96	0.08	965	60
Wembley	-	0.06	0	0
Earls Court and West Kensington	2.07	0.36	2,067	0
Total - other OAs	**4.68**	**0.88**	**4,686**	**435**
Old Oak and Park Royal	6.06	2.06	6,063	2,064
Total – all OAs	***10.74***	***2.94***	***10,749***	***2,499***
Old Oak and Park Royal (%)	56.4%	70.1%	56.4%	82.6%

When combined with the additional demands and wastewater discharge from Old Oak and Park Royal, the demands and discharges generated from growth within the other Opportunity Areas linked to the same drainage system represents a significant increase in pressure on the already constrained infrastructure.

APPENDIX B
Asset Database


Legend
OPDC Boundary
Aqueducts
Bridges
Canal
Stonebridge
Harlesden
College Park
Park Royal
North Acton
West Acton
Old Oak Common
Grand Union Canal
Paddington Branch
Wormwood Scrubs Park
Little Wormwood Scrubs (Recreation Ground)
Linford Christie Stadium
Willesden New Cemetery
Willesden Jewish Cemetery
Roundwood Park
King Edward VII Recreation Ground
St Mary's RC Cemetery
Royal Mail Distribution Centre
Brent Junction
Willesden Junction
Wesley Playing Fields
North Acton Playing Fields
Northfield Ind Est
Tudor Estate
Grand Union Ind Est
Premier Park
Business Park
The Mill Trading Estate
Bush Industrial Estate
Oakwood Business Park
Terminal
Superstore
Carriage Shed
Old Oak Common Sidings
HM Prison Wormwood Scrubs
N
0
0.5
KILOMETRES
SCALE: 1:11,500


Legend
OPDC Boundary
Operational Site
Chamber
Weir
Distribution Main
Trunk Main
Gravity Sewer
Stonebridge
Harlesden
Park Royal
College Park
North Acton
Old Oak Common
West Acton
EALING
Wormwood Scrubs Park
Little Wormwood Scrubs (Recreation Ground)
Willesden New Cemetery
Willesden Jewish Cemetery
St Mary's RC Cemetery
Business Park
The Mill Trading Estate
Grand Union Canal
Paddington Branch
N
0
0.5
KILOMETRES
SCALE: 1:12,000

APPENDIX C
Opportunity Area Strategic Flood Risk Assessment

Introduction

This Appendix sets out the Strategic-Level Flood Risk Assessment for the Old Oak Common and Park Royal Integrated Water Management Strategy (the 'Strategy').

Aims

The aim of the strategic-level flood risk assessment is to:

- Identify the main sources of flood risk to the development using best available historical and flood risk datasets and studies made available by London Boroughs, the Environment Agency, Thames Water and other strategic stakeholders.
- Assess all sources of flooding (including fluvial, tidal, surface water, groundwater, sewer and artificial sources) to the ODPC area and consider the flood risk implications within the wider Counters Creek catchment.
- Review the Environment Agency's 6-year Flood Risk Management Investment Programme and other studies undertaken in the OPDC area to identify those schemes that may have an impact on the Opportunity Areas and the wider Counters Creek catchment, and vice versa.

The outcomes from the assessments are reported alongside recommendations for developments in the area, and supported by mapped outputs of the different sources of flood risk to the OPDC area and wider catchment.

Existing Evidence Base

The flood risk evidence base for the Opportunity Area is extensive. The documents outlined in Table C1 have been reviewed as part of this assessment alongside historical records and further information provided by various. stakeholders.

Table C1: Existing Evidence Base for Old Oak Common & Park Royal Opportunity Area

Evidence	Link
Strategic Flood Risk Assessment	LB Ealing (2008) http://www.ealing.gov.uk/downloads/download/564/ldf_evidence_base_strategic_flood_risk_assessment LB Brent (Level 1 – 2007, Level 2 – 2010 (Sequential Test)) https://www.brent.gov.uk/services-for-residents/planning-and-building-control/planning-policy/flooding-and-flood-risk/ LB Hammersmith and Fulham http://www.lbhf.gov.uk/Images/LBHFSFRA_Final_tcm21-148443.pdf
Local Flood Risk Management Strategy	LB Ealing (draft, December 2014) http://www.ealing.gov.uk/download/downloads/id/9272/local_flood_risk_management_strategy_draft LB Brent (draft, July 2015) http://brent-consult.objective.co.uk/portal/ens/htdel/flood_risk_strategy_3?tab=files
Preliminary Flood Risk Assessment	LB Ealing (2011) LB Brent (2011) LB Hammersmith and Fulham (2011) http://webarchive.nationalarchives.gov.uk/20140328084622/http:/www.environment-agency.gov.uk/research/planning/135542.aspx#9

Evidence	Link
Surface Water Management Plan	LB Ealing London Borough of Ealing –Surface Water Management Plan (2011) LB Brent www.brent.gov.uk/media/documentlibrary/servicesforresidents/planningbuildingcontrol/planning/planningpolicy/ldfrelated/ldfsupportingdocuments/wembleyareaactionplan/climatechange/3501160/W8.3%20Brent%20Surface%20Water%20Management%20Plan.pdf www.brent.gov.uk/media/documentlibrary/servicesforresidents/planningbuildingcontrol/planning/planningpolicy/flooding/9515010/Surface%20Water%20Management%20Plan%20Appendices.pdf LB Hammersmith and Fulham London Borough of Hammersmith and Fulham – Updated Surface Water Management Plan (July 2015)
Regional Flood Risk Appraisal for Greater London	London Regional Flood Risk Appraisal - First Review (August 2014) http://www.london.gov.uk/sites/default/files/Regional%20Flood%20Risk%20Assessment%20-%20First%20Review%20-%20August%202014.pdf
Thames River Basin District Flood Risk Management Plan	Draft (October 2014): https://consult.environment-agency.gov.uk/portal/ho/flood/draft_frmp/consult
Individual Flood Risk Studies	Wormwood Scrubs Surface Water Management Scheme – Feasibility Study (July 2012)
Environment Agency	Flood Risk Mapping (provided for the study and available here: http://watermaps.environment-agency.gov.uk/wiyby/wiyby.aspx?topic=floodmap#x=357683&y=355134&scale=2) • Risk of flooding from Surface Water • Risk of flooding from Rivers and Sea • Risk of Flooding from Reservoirs • Flood map for Planning (Rivers and Sea)
Thames Water	Counters Creek: http://www.thameswater.co.uk/counterscreek/17222.htm
Flood Risk Assessments for Major Developments	London West Midlands Environmental Statement Volume 5 | Technical Appendices CFA4 | Kilburn (Brent) to Old Oak Common Flood risk assessment (WR-003-004) (November 2013) London West Midlands Environmental Statement Volume 5 | Technical Appendices CFA5 | Northolt Corridor Flood risk assessment (WR-003-005) (November 2013)

Sources of Flood Risk

Flood Risk Summary to Old Oak Common & Park Royal

Table C2 presents a summary of the flood risk from all sources to the study area, based on the datasets outlined in Table C1 as well as historical flood risk incident data received from various Risk Management Authorities. Historical flood records are shown in Figure C1 below.

Table C2 Summary of flood risk for all sources of flooding

Flood Source	Flooding Pathways & Historical Flooding	Summary of Risk
Fluvial	– The Brent is reported to flood regularly along its floodplain during periods of high rainfall or when the Welsh Harp Reservoir opens its flood gates to relieve pressure on the reservoir. Ealing Council Records indicate that areas previously affected by flooding from the Brent include: – Ealing Golf Course – Perivale Bridge Playing Fields – Perivale Park Golf Course – Brent Valley Golf Course – Flooding is reported to have occurred in 1977, 1927, 1928 (Ealing SFRA) – The River Brent is reported to have flooded close to the crossing of the A4005 Hanger Lane within Perivale Park Golf Course.[1] – The LB Brent SFRA listed several major flood events on the River Brent (1928, 1977, 1988, 1990 and 2000) and on the Wealdstone Brook (15 flood events between 1928 and 1981), though specific locations are not provided. The LB Ealing SFRA reports flooding to have occurred in 1977, 1927, 1928.	– The majority of the Opportunity Area (and all of the Old Oak Common area) is in Flood Zone 1. – The northwest of Opportunity Area within Park Royal is in Flood Zones 2 and 3 of the River Brent, and lies within the natural floodplain. No built development is proposed within these higher risk flood zones as part of the regeneration proposals for Park Royal. – Overall, fluvial flood risk to the Opportunity Area is low.
Tidal	– No Source of flooding	– No risk
Surface Water	– Victoria Road within the study area has reported surface water flooding in August 2004 and minor flooding in May 2006. (Ealing SFRA) – Brent is very fortunate not to have experienced major flooding incidents in last 20 years. The most recent floods were in 2007 and 2010 and much of this occurred on the highway, open spaces and gardens. – The LB Brent PFRA reports that a number of properties flooded during the July 2007 event, although the exact location of the flooded properties was not provided. The main cause of flooding was a combination of surface water runoff and inadequate sewer capacity. Anecdotal information has shown that the A4000 Victoria Road Bridge, close to the junction with Chandos Road, flooded in August 2004. – Critical Drainage Areas (CDAs) are located within the study area and	– The Ealing SFRA reports that drainage flooding within the study area can be attributed to either a lack of capacity or due to infrastructure failure. – Flooding is likely to be severe and of longer duration in low lying areas but local problems may result in all areas as a result of very heavy rain or infrastructure failure (Ealing SFRA). – Generally, surface water flood risk is low across the majority of the study area, being largely constrained to roads, railways and areas adjacent to railway embankments. – Areas of higher risk including surface water have been identified and are reported in subsequent subsections of this assessment. –

[1] London West Midlands Environmental Statement Volume 5 \| Technical Appendices CFA5 \| Northolt Corridor Flood risk assessment (WR-003-005) (November 2013)

Flood Source	Flooding Pathways & Historical Flooding	Summary of Risk
	detailed within this FRA,	

Groundwater	– The LB Ealing PFRA identifies a number of groundwater flooding incidents within the wider Borough, with the nearest to the study area occurring to the south-east of Hanger Lane Station (south west corner of Park Royal).
	– Groundwater flooding has not been a significant issue for the study area and the only historical record identified was during 2000/01 (Ealing SFRA).
	– The PFRA reports do not show any areas to have an increased potential for elevated groundwater.
		– The majority of the Opportunity Area is underlain by the impermeable London Clay layer. The geological succession beneath the London Clay comprises: [2]
		  – the Harwich Formation;
		  – the Lambeth Group;
		  – the Thanet Sand Formation; and
		  – the Cretaceous Chalk Group.
		– Along the River Brent valley (and hence the western boundary of the Park Royal site) there are potentially water-bearing superficial deposits comprising alluvium and river terrace deposits (Taplow Gravel and Kempton Park Gravel) associated with the river and floodplain corridor. Shallow groundwater is likely to be in continuity with surface water in the River Brent. A further narrow ribbon of alluvial deposits is also present in the western part of the study area, along Greenford Road, which is associated with a now culverted stream.
		– The eastern boundary of the study area and the Brent floodplain appears to be at a higher risk of potential groundwater flooding due to the presence of superficial deposits. (Ealing SFRA). Overall the groundwater flood risk is considered to be low.
		– It is recommended that for development in areas identified as 'high risk', further analysis should be carried out to determine the presence of groundwater onsite. (Ealing SFRA)

Sewer	– The PFRAs and SFRAs within the study area have reported a number of historical incidents of sewer flooding, however, the exact location of these events is not available in every case. – Several Thames Water sewer flooding records have been recorded in the study area, mostly within Park Royal. Several flooding incidents have been recorded either side of Acton Lane to the north-east of Central Middlesex Hospital. Within Old Oak, three incidents were recorded just south of North Action tube station. – More widely, the LB Ealing SFRA notes the susceptibility and historical occurrence of flooding from overloaded	– Sewer flood risk is considered to be high South of North Acton Railway line (Ealing SFRA). – TWUL historical DG5 sewer flooding records presented in the PFRA reports show that there have been a number of sewer flooding incidents within the study area. Records are available within the respective PFRA reports to a resolution of four-figure postcode sector references. To the south-west of the proposed HS2 station at Old Oak Common and the proposed Victoria Road crossover box there are two further adjacent postcode areas where again sewer flooding incidents have occurred and have been recorded in the 21- 50 range and 51-100 range respectively. [3] – Sewer flood risk is considered to be moderate

[2] London West Midlands Environmental Statement Volume 5 | Technical Appendices CFA4 | Kilburn (Brent) to Old Oak Common Flood risk assessment (WR-003-004) (November 2013)

[3] London West Midlands Environmental Statement Volume 5 | Technical Appendices CFA4 | Kilburn (Brent) to Old Oak Common Flood risk assessment (WR-003-004) (November 2013)

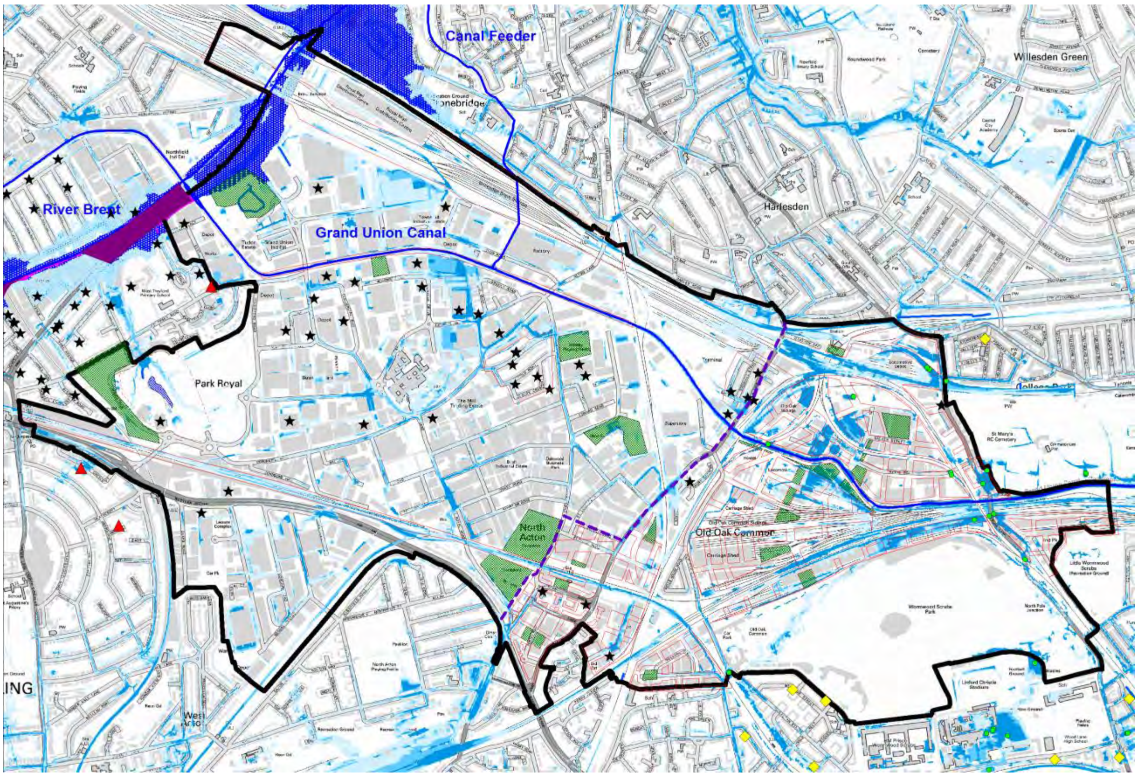
Flood Source	Flooding Pathways & Historical Flooding	Summary of Risk
	sewers within the borough, particularly within Northolt and Greenford, with recorded flood events in Acton during the 2007 flood event. The SFRA identifies a total of 140 properties have flooded in Ealing from the foul water drainage systems and 30 properties have flooded as a result of surcharging of surface water sewers in the past 10 years, with a further 135 properties affected by flooding from combined systems in the same time period. The majority of these incidents are in Acton, south of the Study Area. – Property flooding from combined sewers occurs within the wider counters creek catchment (to which Old Oak and parts of Park Royal drain) due to lack of capacity within the wider drainage network. Surface water and foul water flow increases from the proposed development could exacerbate this risk if not mitigated.	across within Park Royal and the south east section of Old Oak.
Artificial – Grand Union Canal	– The Grand Union Canal (GUC) has overtopped historically further west in Ealing (1977, 1992 and 2000); however, there are no historical recorded incidents of flooding from the canal within the study area. – The RBKC and LBHF SFRA states that the Grand Union Canal (Paddington Branch) in the north of the two boroughs is likely to act as a conveyor of surface water in an extreme event and it is likely to convey flow out of the boroughs due to the topography. – The Canal & River Trust (formerly British Waterways) is responsible for the maintenance of the canal network and has confirmed that there are 43km of unrestrained water (i.e. no locks) on this reach of the Grand Union Canal (Paddington Branch).[4] – Within the site, the Grand Union Canal (Paddington Branch), close to Old Oak Common, is retained on the southern side and managed water levels are approximately 1.75m above surrounding ground levels, rising to 4.5m. The towing path is 2.5m wide. Further to the west the towing path is on the south side of the canal at a level of approximately 30m AOD. Ground levels in the existing GWML railway to the	– The Grand Union Canal is a significant water course running through the study area and poses a residual flood risk. Since there is a strict maintenance programme in place managed by British Waterways, any potential breach is likely to be picked up before any serious flooding occurs. As such a breach of Grand Union Canal is considered a residual risk. (Ealing SFRA) – Condition survey reports were reviewed for the Grand Union Canal as part of the HS2 Environmental Statement and breach modelling was undertaken. The canal currently poses a flood risk to the site of the proposed HS2 station and surrounding area. Two-dimensional hydraulic modelling has been undertaken to determine the extent and depth of flooding associated with a breach of the retaining wall of the canal. For the baseline case (no HS2 works), breach flood waters will flow to the south before entering the track beds of the GWML. Flood waters will travel to the east and to the west along the GWML. Flood waters will also flow overland across Wormwood Scrubs Common.[5] – Depths of flooding are expected to be in the order of approximately 0.2m–1m depending on the location of the assessment point, and the expected width of breach. – Due to the management and maintenance of the canal and the limited extent of breach

[4] London West Midlands Environmental Statement Volume 5 | Technical Appendices CFA4 | Kilburn (Brent) to Old Oak Common Flood risk assessment (WR-003-004) (November 2013)

[5] London West Midlands Environmental Statement Volume 5 | Technical Appendices CFA4 | Kilburn (Brent) to Old Oak Common Flood risk assessment (WR-003-004) (November 2013)

Flood Source	Flooding Pathways & Historical Flooding	Summary of Risk
	south are approximately 25m AOD and the managed water level in the canal is therefore approximately 4.5m above ground levels on the site. The land continues to fall away to the south through Wormwood Scrubs Common towards mixed land use including the residential area at Wulfstan Street, Wormwood Scrubs Prison, Queen Charlotte's & Chelsea Hospital, Hammersmith Hospital, Burlington Danes School and the Linford Christie Athletics Stadium.	water, it is therefore concluded that there will be a low residual risk of flooding from the Grand Union Canal (Paddington Branch) to the area, due to the failure of the canal retaining structures. [6] –
Artificial – Welsh Harp Reservoir	– A dam break was experienced in the 1940's causing significant flooding apart form that incidence, due to a strict maintenance regime, only minor seepages and leakages have been reported. (Ealing SFRA)	– The river valley of the River Brent, to the northwest of the site, lies within the maximum extent of flooding from the Welsh Harp Reservoir. However, proposed development is not located within this flood extent and hence the risk from breach or dam break of the Welsh Harp Reservoir is concluded to be low.

Figure C1: Historical flood records in the study area:



[6] London West Midlands Environmental Statement Volume 5 | Technical Appendices CFA4 | Kilburn (Brent) to Old Oak Common Flood risk assessment (WR-003-004) (November 2013)

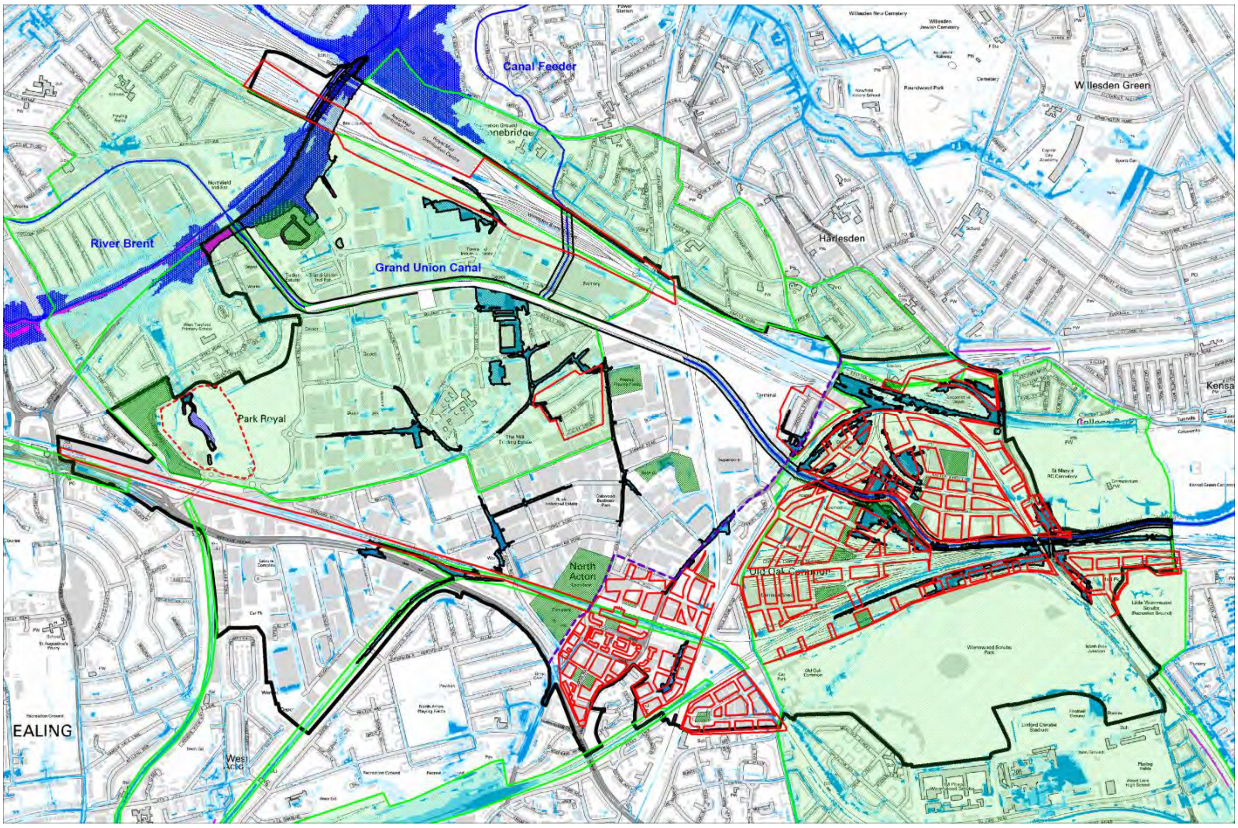
Critical Drainage Areas (CDAs)

The SWMPs undertaken for the London Boroughs of Brent, Ealing and Hammersmith & Fulham identified a number of CDAs covering the Opportunity Area as identified in Figure C2 and described in Table C3.

Table C3: Surface Water Critical Drainage Areas

Borough	CDA	Location	Description
Ealing	Group1_009	Flooding of Network Rail tracks between Ealing Broadway station to Acton mainline station, and the LUL arms of this section up to Park Royal via North Ealing, and up to A40 via West Acton	The Drain London modelling outputs indicated that ponding may occur within the railway cutting as it is a topographical low point within the catchment. The platforms at Acton NR station, West Acton LU station, North Ealing LU station and Park Royal LU station are all at risk of surface water flooding. The hazard on the railway tracks is predicted to be moderate /significant, with some areas identified as an extreme hazard due to the depth of water.
	Group1_011	A40/A406 underpass, near Hanger Lane, Ealing	Surface water is predicted to pond in the low point in road. The hazard within the road is predicted to vary between significant and extreme.
Brent	Group2_043 *Brent_10*	Park Royal	Located in a predominantly commercial area, the main source of flood risk within this CDA is from ponding surface water in topographic depressions. One Local Flood Risk Zone (LFRZ) has been designated in the area at most significant risk of surface water ponding, in the vicinity of Central Middlesex Hospital, Central Way and Coronation Road.
	Group2_042 *Brent_09*	North Circular	A predominantly commercial CDA with a small residential area to the north west. The main source of surface water flood risk within this CDA is ponding flow in topographic low spots. One higher risk area (Local Flood Risk Zone) has been designated within this CDA which corresponds with the significant area of ponding on the A406 North Circular, a regionally important infrastructure asset
Hammersmith & Fulham	Ward Area 1	College Park and Old Oak	This Ward was identified as being at risk from surface water and sewer flooding. The modelling shows that surface water flows from the sloped areas of Wormwood Scrubs Park and Old Oak Common towards the railway embankment to the south. The presence of buildings and the railway line causes surface water to pond in the low lying areas behind the embankment. There is the potential for surcharging of the sewer network at points along Wulfstan Street that would increase surface water flooding along the railway line. The main hazards within the Ward are associated within the areas of deep flooding and where there are high velocities, i.e. the main flow paths along the railway line. There are 39 flooding hotspots within the Ward. There were no Council records of surface water flooding in the Ward during the July 2007 flood event. There are 15 records of flooding recorded on the A40 from TfL records.

Figure C2: Location of Critical Drainage Areas (in green)



High Risk Areas

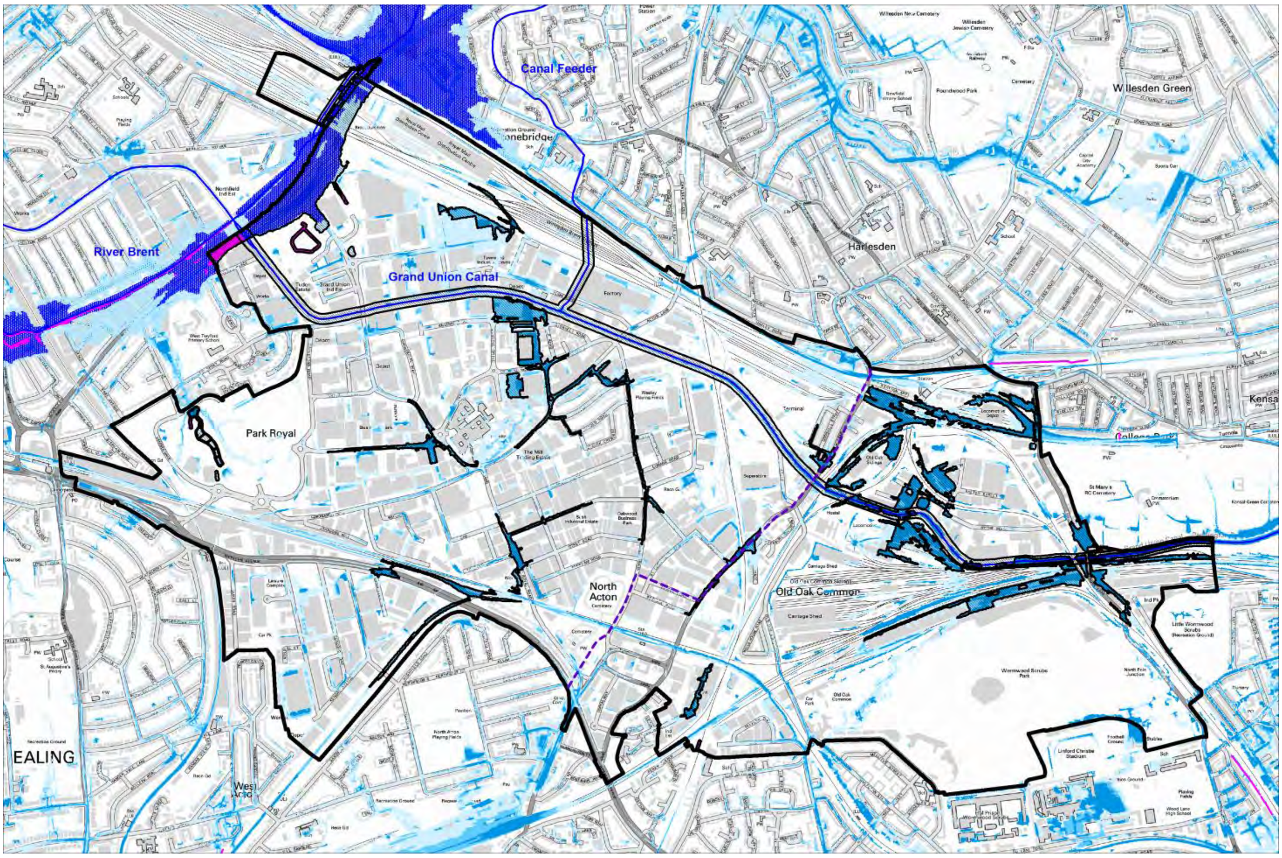
The baseline and historical flooding incident information from all flood risk sources has been used to identify High Risk Areas within the study area; these areas are shown in Figure C3.

These High Risk Areas are locations where one of more flood risk sources result in a higher localised flood risk than the majority of the study area which is concluded to be at low flood risk overall. They have been identified based on land which is located within, or subject to one or more of the following:

- Fluvial Flood Zones 2 or 3;
- Close proximity to water bodies (rivers, canals, ponds or water features) with either historical flood records and or susceptibility to surface water flooding;
- Significant area of land with a modelled surface water flood risk of 'High' (1 in 30 year), or 'Medium' (1 in 100 year);
- More than one historical record of flooding from any source.

These locations, and specific mitigation, should be considered carefully when considering individual planning applications in these locations. With respect to intensification of Park Royal land uses, proposals for additional development should preferentially be steered away from these higher risk areas. For Old Oak, consideration should be given at masterplanning stage to plot layout and provision of green space, allowing space for flood waters specifically associated with surface water.

Figure C3: High Risk Areas within the study area (black outline)



Impacts of Other Major Development in Area

HS2 development

There is the potential for the proposed HS2 scheme to change the baseline risk of flooding described in this appendix. Though designed such that the probability of the Proposed Scheme flooding in any given year is less than 1 in 1,000, any change to the baseline risk of flooding could impact on the assessment of flood risk within the Opportunity Area.

A review of the HS2 flood risk assessments within the Environmental Statement suggests that only baseline surface water flood risk would be altered by the HS2 scheme.

The above ground infrastructure has the potential to alter overland flow routes for surface water, thereby changing the risk of flooding to local receptors. Surface water runoff from all permanent structures will be controlled at source by design and will prevent increased rates and volumes of surface water runoff overland flow to the local sewer network or above ground receptors.

Old Oak Common Station

Significant land levelling works are proposed at Old Oak Common station. These works will therefore change the natural overland flowpaths and the location of predicted surface water flooding. However, there are no distinct flowpaths crossing the Old Oak Common station site, and the surface water flood risk at the shafts and station building is therefore unlikely to increase.

Surface water will be collected in the station drainage network and attenuated up to the 1 in 100 years return period (1% annual probability) rainfall event including an allowance for climate change. Attenuation volumes up to a maximum of 7,100m^3 are proposed in the vicinity of the station. The design states that the provision of SuDS should be considered, such as green roofs/porous paving. Attenuated surface water will be discharged to the local Thames Water sewer network. Any connection will be agreed in advance with Thames Water.

The Proposed Scheme will therefore not lead to a change in the risk of flooding from surface water sources at Old Oak Common station. There will therefore be no adverse effects on the risk of flooding from surface water at Old

Oak Common Network Rail depot, Wormwood Scrubs Common or East Acton urban centre arising from the Proposed Scheme.

A4000 Victoria Road Bridge

The widening of the A4000 Victoria Road is proposed to accommodate traffic requirements for Old Oak Common as development proposals expect an increase in traffic movement. The design states that one half of the carriageway will continue to drain to the existing sewer network and the widened part of the road will be restricted to like-for-like runoff rates based on 50mm/hr. Oversized pipes in the order of 1050mm in diameter will be required in order to achieve the attenuation required.

The Proposed Scheme will not lead to any increase in the risk of flooding from surface water sources at the A4000 Victoria Road Bridge.

Flood Risk Management

The linkage of existing proposed flood risk management measures with existing or planned flood risk management schemes offer the potential to work with other parties to deliver wider flood risk management benefits that benefit the Old oak Common & Park Royal Opportunity Areas and their regeneration.

Planned Flood Management Schemes

Environment Agency schemes

The Environment Agency is managing a six-year flood risk management investment programme[7]. Whilst none of the projects within the six year plan lie in the Old Oak Common & Park Royal Opportunity Area, some of the projects could benefit the regeneration of Park Royal and Old Oak and could combine with wider water management solutions proposed through the Strategy.

- To the east – Camden West Surface Water FAS.
- To the north – Wealdstone Brook FAS.

Potential Flood Management Schemes

Surface Water Management Schemes

A number of surface water management mitigation schemes were identified for CDAs in the the London Boroughs of Ealing, Brent and Hammersmith & Fulham. These were assessed as part of the SWMP and a preferred option identified for each CDA, with associated costs and potential benefits. Details are provided in Table C4

Table C4: Surface Water Mitigation Schemes within Critical Drainage Areas

Borough	CDA	Location	Preferred Option
Ealing	Group1_009	Flooding of Network Rail tracks between Ealing Broadway station to Acton mainline station, and the LUL arms of this section up to Park Royal via North Ealing, and up to A40 via	The preferred option for CDA_009 is to reduce ground levels within the identified open space areas near the CDA (within overland flow path areas), to provide storage for depths up to 30cm, footpath and kerb modifications are also recommended for nearby roads to promote flow into these areas of open space. This option is estimated to cost in between £501k – £1m. A flood plan should also be put in place, linked to extreme rainfall alerts that would enable alternative transportation options to be put in place, minimising disruption to network rail users. A plan should already be in use for the stations predicted to be affected by the surface water flooding.

[7] Environment Agency six-year flood risk management investment programme: https://www.gov.uk/government/publications/programme-of-flood-and-coastal-erosion-risk-management-schemes

Borough	CDA	Location	Preferred Option
		West Acton	Other measures that were considered include the "do nothing" scenario or provide flood storage within the railway corridor.
	Group1_011	A40/A406 underpass, near Hanger Lane, Ealing	The preferred option for this CDA was to provide underground storage beneath the A40 and improve entry capacity. It was also recommended that a flood plan is implemented (or revised if in existence) as this area is considered critical transport infrastructure of local significance. This preferred option will reduce the depth of flooding in the area and is estimated to cost between £251k and £500k. Other measures that were considered include the "do nothing" scenario and increasing the drainage capacity beneath the A40. Increasing the drainage capacity beneath the A40 depends on existing services beneath the road and the impact on the downstream capacity. This measure has the potential to increase flood risk downstream if the drainage system's capacity is limited – but could be reviewed during a detailed feasibility study.
Brent	Group2_043 *Brent_10*	Park Royal	To mitigate the flood risk in this area, the preferred option was to install a series of roadside rain gardens along Cumberland Avenue, Willenfield Road, Abbey Road and Central Way will help to intercept and reduce surface water runoff in this CDA. The proposed measures estimated cost: Roadside Rain Garden < £25k The proposed measures will help to reduce surface water runoff through the commercial areas. This option will not completely eliminate the risk posed to property but it should mitigate the risks and help reduce the deeper areas of ponding.
	Group2_042 *Brent_09*	North Circular	To mitigate the flood risk in this area, the preferred option was to install six additional gully points in the A406 underpass to improve drainage through the underpass. The proposed measures estimated was: Additional Gully Point which had an estimated cost of under £25k. The proposed measures will help to reduce localised surface water ponding on the A406 North Circular. This option will not completely eliminate the risk posed to property but it should mitigate the risks and help reduce the deeper areas of ponding. A full assessment of the current drainage and pumping capacity of the system through the underpass by TfL would be beneficial as this is such a key transport route within the Borough.
Hammersmith & Fulham	Ward Area 1	College Park and Old Oak	There is a tendency for surface water to flow off the higher ground of Wormwood Scrubs in College Park and Old Oak. Therefore, an option would be to intercept these flows and so prevent the runoff of surface water to the more vulnerable residential and commercial areas to the south. This could be accomplished through the creation of a detention basin or flood storage bunds along the southern extent of Wormwood Scrubs and Old Oak Common. These would act to intercept the main flow paths runoff off the park area to the north of the Linford Christie Stadium, HM Wormwood Scrubs Prison and to the north of Braybrook Street. Three flood storage bunds were modelled within the Wormwood Scrubs area. During the 5% AEP modelled rainfall event, these 3 storage areas have been modelled to collectively retain

Borough	CDA	Location	Preferred Option
			approximately 5,800m^3 of surface water runoff that has been intercepted from the Wormwood Scrubs area. This has a significant effect on the flood depths downstream, with the most notable benefit of a 0.1-0.15m reduction in flood depths within the area of the Hammersmith Hospital. Further to the west, the flood storage bund shows a reduction in flood depths of up to 0.15m along Wulfstan Street for the same return period event. The flood storage bunds have been modelled to effectively retain surface water runoff for all of the modelled return period events. The greatest flood depth reduction can be seen for the 1% and 0.5% AEP events, during which the greatest volumes of surface water are retained. Indicative costs for the construction of these flood storage areas have been undertaken utilising cost estimates provided in the Spons: Civil Engineering and Highways (2013).Wormwood Scrubs and Old Oak Common: The construction of the three flood storage bunds would cost in the region of £51k to £100k.

Wormwood Scrubs Surface Water Management Scheme

The LBHF undertook a study in 2012 to assess the feasibility of, and the costs and benefits associated with a scheme to attenuate surface water run-off and improve the quality of the open space and biodiversity of Wormwood Scrubs[8].

The study involved the following key tasks:

- A hydrological assessment to calculate the storage volumes required to attenuate surface run-off,
- Calculation of the design, construction and maintenance costs of the scheme,
- Economic appraisal of the scheme,
- Assessment of the contaminated land on-site,
- Cultural heritage appraisal.

An Outline Design for the wetland area was completed based on the wetland storage volumes calculated by the hydrological assessment. The proposals include an interlinked system of attenuation ponds, wetlands and wet swales, which focuses on maximising benefits for surface water management, biodiversity and amenity.

The design, construction and maintenance costs of the wetland scheme were calculated assuming a 1:30 year and 1:100 year design horizon. Detailed design costs were estimated as £130,000, and construction costs were estimated to be £1.73 million (for a 1:30 year design) and £2.18 million (for a 1:100 year design). Ongoing maintenance costs were been calculated as £4,000 per year and the design life of the wetland is estimated to be 75 years.

The cost-benefit analysis identified the reduction in flood damages to Wormwood Scrubs prison, Linford Christie stadium and Hammersmith Hospital and indicated that the benefit-cost ratios would be 14.32 and 13.33 for a 1:30 year and 1:100 year design horizon, respectively. However, the outcomes from the Defra Partnership Funding Calculator indicated that external funding contributions or a reduction in scheme cost would be required to make the scheme eligible for Flood Defence Grant in Aid funding.

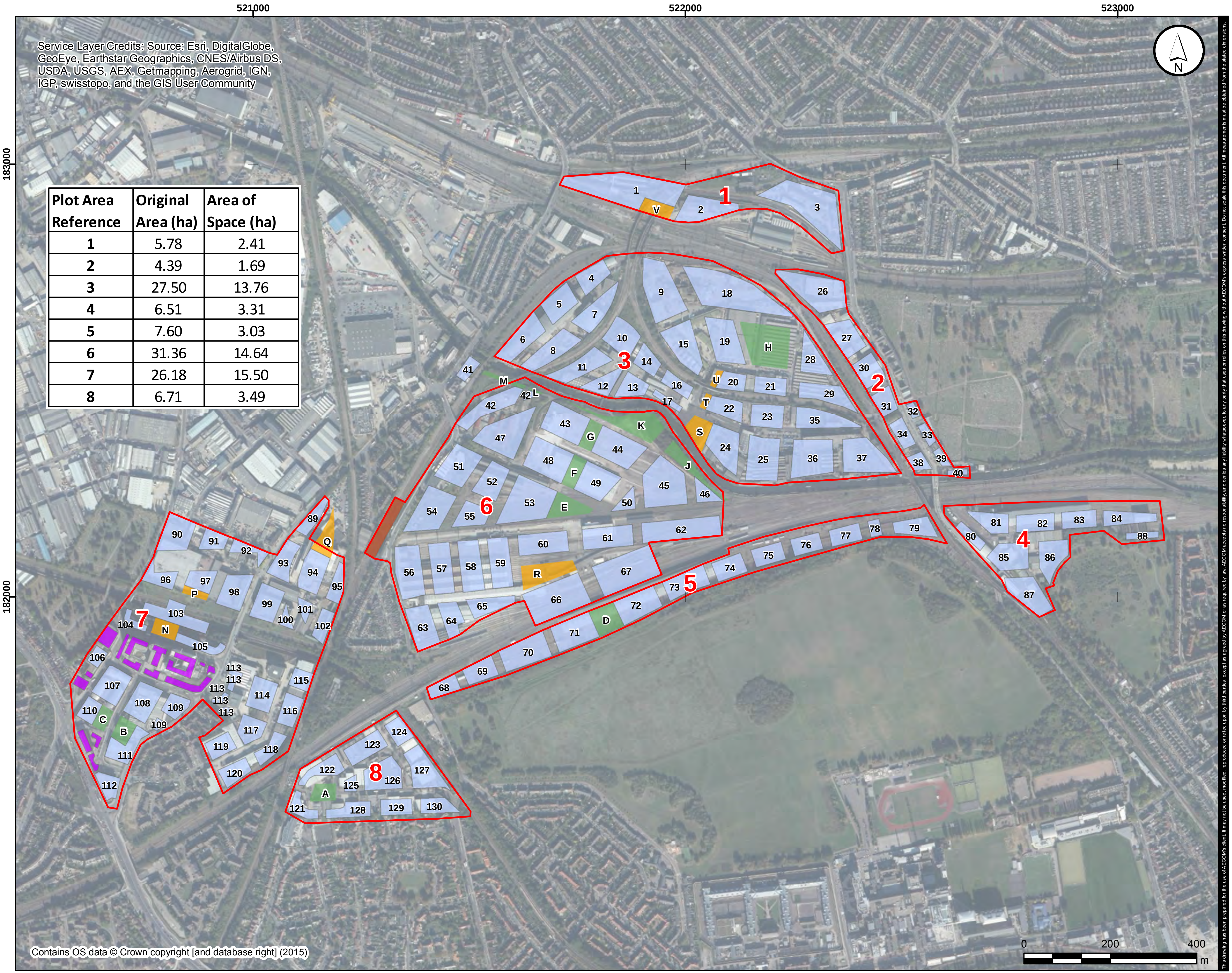
Proposals for managing surface water runoff from the development within the Study area could potentially be combined with a wider scheme to benefit property and areas at risk of flooding to the south of Wormwood Scrubs.

[8] Halcrow, 27 July 2012, London Borough of Hammersmith & Fulham - Wormwood Scrubs Surface Water Management Scheme – Feasibility Study

Potential Opportunities and Recommendations

- A drainage study is being carried out by Thames Water in order to establish the flow characteristics and capacity in the River Brent and associated drainage system. On completion of this study, this will provide detail information on areas affected by flooding and solutions. The study is being carried out on behalf of North Brent and Harrow Flood Stakeholders Group. This group comprises of representatives from Brent, Harrow, Thames Water and Environment Agency; this study may identify capacity for discharge of attenuated surface water from Park Royal to the River Brent.
- In managing residual risk from canal breach flooding, it is recommended that development in Old Oak Common is set back from the canal. This is in keeping with the current masterplan proposals to create a green corridor along the canal;
- Development in the north west of Park Royal should be set back from the River Brent edges to enable a range of additional flood risk management options for the wider Brent corridor;
- Areas of green space proposed within the early Old Oak Common masterplan could be re-configured to coincide with areas of existing ponding to act as areas of dispersed attenuation storage.
- LBHF has considered the feasibility of providing storm water attenuation within Wormwood Scrubs to reduce the risk of flooding to property and infrastructure to the south of the Scrubs within the Borough. This could be combined with storm water attenuation from the Opportunity Area to provide benefit both to the Opportunity Area and the wider drainage catchment to the south.
- Thorough retrofit of the Park Royal section of the site, there are opportunities for Blue Corridors (via raised kerbs) particularly around the high risk areas and associated roads identified to the south of the canal within the current industrial areas.

APPENDIX D
Plot Grouping Figures



Plot Area Reference	Original Area (ha)	Area of Space (ha)
1	5.78	2.41
2	4.39	1.69
3	27.50	13.76
4	6.51	3.31
5	7.60	3.03
6	31.36	14.64
7	26.18	15.50
8	6.71	3.49

AECOM

PROJECT

OLD OAK COMMON AND ROYAL PARK DEVELOPMENT

CLIENT

OLD OAK COMMON DEVELOPMENT CORPORATION

CONSULTANT

AECOM Limited
1 Callaghan Square
Cardiff, CF10 5BT
+44 (0)29 2067 4600 tel
www.aecom.com

LEGEND

- Plot Boundaries
- Old Oak Common - Plots
- Development complete
- New London Overground Station – no over station development
- Green Space
- Open Space

ISSUE/REVISION

I/R	DATE	DESCRIPTION
A	02/09/2015	ISSUED FOR INFORMATION

KEY PLAN

CONTRACT NUMBER

XXXXXXXXXX

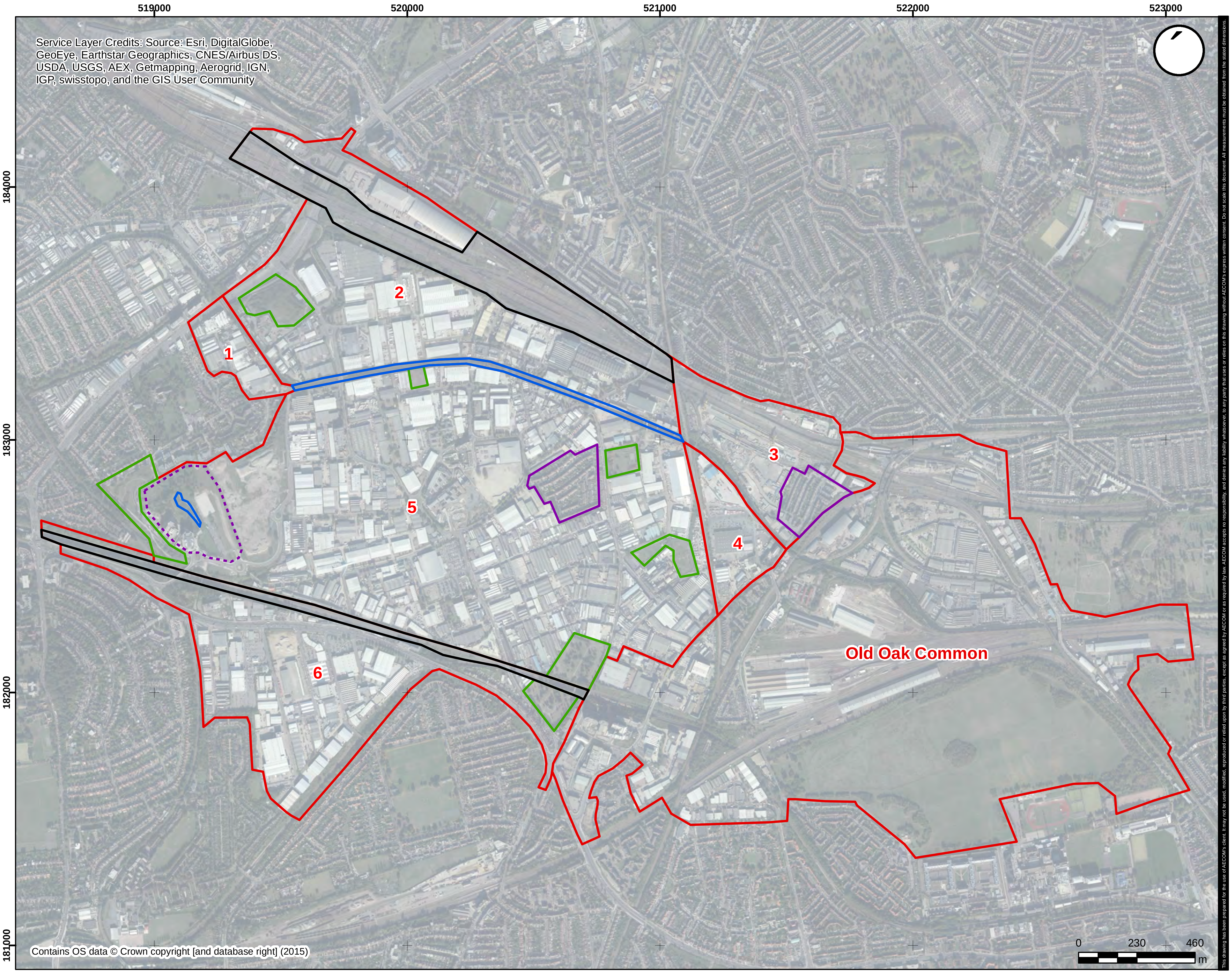
SHEET TITLE

FIGURE 1
Old Oak Common - Plot Locations

Scale at A3: 1:7,898.35

SHEET NUMBER

Figure 1 - Old Oak Plots_v3 v1



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LEGEND

- Catchment
- Green Space
- Waterbody
- Rail Track
- Residential
- Proposed Residential

ISSUE/REVISION

I/R	DATE	DESCRIPTION
A	11/09/2015	ISSUED FOR INFORMATION

KEY PLAN

CONTRACT NUMBER

XXXXXXXXXX

SHEET TITLE

Figure 4 - Park Royal Sub-Catchments

Scale at A3: 1:13,500

SHEET NUMBER

150911_ParkRoyalSubCatchments v1

Last saved by: davidac Last plotted:11/09/2015 Coordinate System: British National Grid (OSGB 1936)
Filename: F:\Library\GIS_DATA\Projects\Counters_Creek\Maps\150911_ParkRoyalSubCatchments.mxd

APPENDIX E
Rainfall Runoff Calculations

Starting Information

→ HS2 and New Rail station to be constructed next to Old Oak Common.
→ High density housing proposed beside common and in surrounding area.
→ Area split into different plots.
→ Climate change factor (+30%)- residential area (+30%), commerical area (+20%)
→ Greenfield run off rates - Not impermeable

→ Microdrainage used to calculate the permitted outflow.
- ihs 124 methodology
- 50 hec or more catachment (l/s/hec)

→ M5-60 - M= how many years, 5= no. of years, 60= 60 min duration

→ All coordinates obatined from www.streetmaps.co.uk

IH 124 Mean Annual Flood

Input

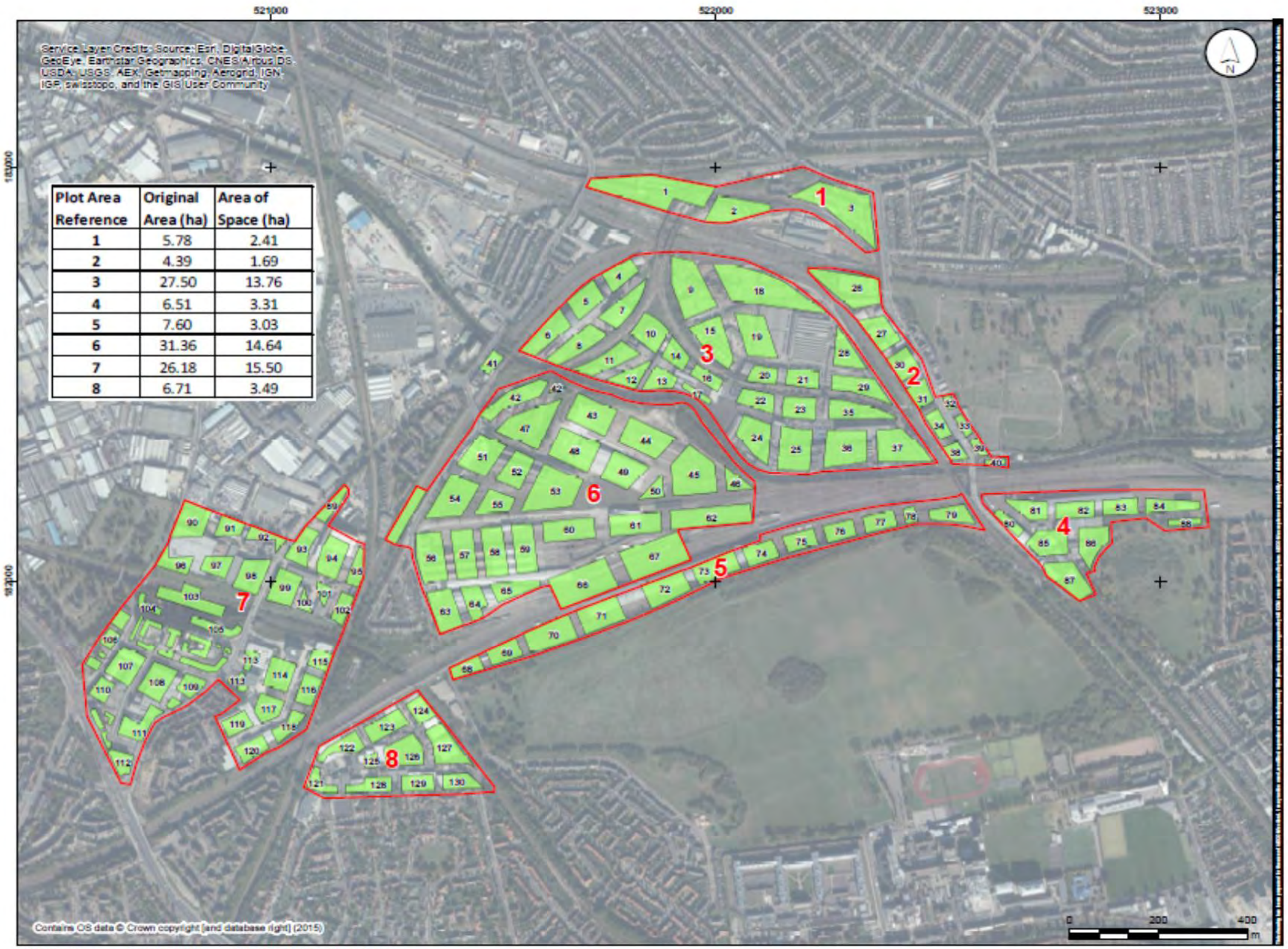
Return Period (years)	100	Soil	0.450
Area (ha)	50.000	Urban	0.000
SAAR (mm)	633	Region Number	Region 6

Results	**l/s**
QBAR Rural	195.3
QBAR Urban	195.3
Q100 years	622.9
Q1 year	166.0
Q2 years	172.0
Q5 years	249.9
Q10 years	316.3
Q20 years	391.2
Q25 years	419.4
Q30 years	442.5
Q50 years	511.6
Q100 years	622.9
Q200 years	732.2
Q250 years	767.4
Q1000 years	1007.6

Sections

Old Oak - Future	Total Area (ha)	Total Area (m^2)	Area of Open Space (ha)	Area of Open Space (m^2)	Impermeable (ha)	Impermeable (m^2)	Easting/Northing	Lat/Lon
1	5.78	57800	2.41	24100	3.37	33700	522240, 183165	51.534,-0.239
2	4.39	4390	1.69	16900	2.7	27000	522450, 182534	51.528449,-0.236198
3	27.5	27500	13.76	137600	13.74	137400	521950, 182559	51.528782,-0.243394
4	6.51	6510	3.31	33100	3.2	32000	522660, 182364	51.526876,-0.233232
5	7.6	7600	3.03	30300	4.57	45700	521975, 182054	51.524238,-0.243208
6	31.36	31360	14.64	146400	16.72	167200	521495, 182234	51.525959,-0.250061
7	26.18	26180	15.5	155000	10.68	106800	521072, 182049	51.524387,-0.256219
8	6.71	6710	3.49	34900	3.22	32200	521299, 181609	51.520384,-0.253100

Old Oak - Existing	Total Area (ha)	Total Area (m^2)	Area of Open Space (ha)	Area of Open Space (m^2)	Impermeable (ha)	Impermeable (m^2)
1	5.78	57800	0.911039936	9110	5	53275
2	4.39	43900	0.248477545	2485	4	41453
3	27.5	275000	2.186055697	21861	27	268109
4	6.51	65100	0.28682015	2868	6	62831
5	7.6	76000	0.477190111	4772	7	72438
6	31.36	313600	1.881702719	18817	31	305522
7	26.18	261800	1.69456418	16946	26	261233
8	6.71	67100	0.034813364	348	7	68682



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AECOM

PROJECT

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www.aecom.com

LEGEND

Plot Boundaries

Old Oak Common - Plots

ISSUE/REVISION

KEY PLAN

CONTRACT NUMBER

XXXXXXXXXX

SHEET TITLE

FIGURE 1
Old Oak Common - Plot Locations

Scale at A3: 1:8,000

SHEET NUMBER

Figure 1 - Old Oak Plots_v2 v1

Project: **60439696**
Ref:
Section:

Made by: **Lilian Gowans** Date: **21 October 2015**
Checked by: **Jon Curry** Date:
Approved By: Date:

DESIGN OF STORMWATER STORAGE FACILITY
Design of stormwater storage facility for section 1.

RAINFALL DETAILS

Wallingford Procedure
Table 6.2
Ratio Z2 (Relationship between rainfall of return period T (MT) and M5 - England and Wales)

M5 Rainfall (mm)	M1	M2	M3	M4	M5	M10	M20	M30 (interpolated)	M50	M100
5	0.62	0.79	0.89	0.97	1.02	1.19	1.36	1.46	1.56	1.79
10	0.61	0.79	0.90	0.97	1.03	1.22	1.41	1.53	1.65	1.91
15	0.62	0.80	0.90	0.97	1.03	1.24	1.44	1.57	1.70	1.99
20	0.64	0.81	0.90	0.97	1.03	1.24	1.45	1.59	1.73	2.03
25	0.66	0.82	0.91	0.97	1.03	1.24	1.44	1.58	1.72	2.01
30	0.68	0.83	0.91	0.97	1.03	1.22	1.42	1.56	1.70	1.97
40	0.70	0.84	0.92	0.97	1.02	1.19	1.38	1.51	1.64	1.89
50	0.72	0.85	0.93	0.98	1.02	1.17	1.34	1.46	1.58	1.81
75	0.76	0.87	0.93	0.98	1.02	1.14	1.28	1.38	1.47	1.64
100	0.78	0.88	0.94	0.98	1.02	1.13	1.25	1.33	1.40	1.54
150	0.78	0.88	0.94	0.98	1.01	1.12	1.21	1.27	1.33	1.45
200	0.78	0.88	0.94	0.98	1.01	1.11	1.19	1.25	1.30	1.40

Extract of Wallingford Procedure Volume 1

RAINFALL DETAILS

M5-60	21	mm	*From Wallingford Procedure, Volume 3; Maps. Rainfall depth (M5-60 minutes)*
r	0.43		*From Wallingford Procedure, Volume 3; Maps. Ratio of M5-60 minutes to M5-two day rainfall*
CC	30%		*Climate change allowance*

DURATION (minutes)	Z1	M5-D (M5-60 x Z1) (mm)	Z2	M100-D (M5-D x Z2) (mm)	M100-D plus CC R (M5-D x Z2) (mm)
5	0.38	7.98	1.86	14.9	19.3
10	0.53	11.13	1.93	21.5	27.9
15	0.63	13.23	1.96	26.0	33.7
30	0.80	16.80	2.00	33.7	43.8
60	1.00	21.00	2.03	42.5	55.3
120	1.20	25.20	2.01	50.6	65.8
240	1.40	29.40	1.97	58.1	75.5
360	1.50	31.50	1.96	61.7	80.2
600	1.70	35.70	1.92	68.7	89.3
1440	2.10	44.10	1.86	81.9	106.5
2880	2.45	51.45	1.80	92.6	120.4

I - O = S
I = inflow
O = outflow
S = storage

I = A x R
A = impermeable contributing area
R = total rainfall

O = a_{s50} x f x D
a_{s50} = internal surface area of soakaway to 50% depth (excluding base)
f = soil infiltration rate
D = storm duration

Project:	60439696		
Ref:			
Section:			
Made by:	Lilian Gowans	Date:	21 October 2015
Checked by:	Jon Curry	Date:	

Contributing Area	33700	m^2
Type of Storage	Lake	
Void Ratio	100	%
Length	N/A	m
Width	N/A	m
Depth	N/A	m
Number of	1	
Safety Factor	1	
Free Volume (Available Storage)	N/A	m^3
Permitted outflow	12.5	l/s/ha

DURATION (minutes)	INFLOW (A x R) (m^3)	OUTFLOW (a_{s50} x *f* x D) (m^3)	REQUIRED STORAGE (I - O) (m^3)
5	651	13	638
10	940	25	915
15	1137	38	1099
30	1475	76	1399
60	1864	152	1712
120	2217	303	1914
240	2544	607	1937
360	2702	910	1792
600	3010	1517	1493
1440	3588	3640	0
2880	4058	7279	0

Maximum Storage required **1937 m^3**

Project: 60439696
Ref:
Section: 1

Made by: Lilian Gowans Date: 21 October 2015
Checked by: Jon Curry Date: 26 October 2015
Approved By: Date:

DESIGN OF STORMWATER STORAGE FACILITY
Design of stormwater storage facility for section 2.

RAINFALL DETAILS

Wallingford Procedure
Table 6.2
Ratio Z2 (Relationship between rainfall of return period T (MT) and M5 - England and Wales)

M5 Rainfall (mm)	M1	M2	M3	M4	M5	M10	M20	*M30 (interpolated)*	M50	M100
5	0.62	0.79	0.89	0.97	1.02	1.19	1.36	*1.46*	1.56	1.79
10	0.61	0.79	0.90	0.97	1.03	1.22	1.41	*1.53*	1.65	1.91
15	0.62	0.80	0.90	0.97	1.03	1.24	1.44	*1.57*	1.70	1.99
20	0.64	0.81	0.90	0.97	1.03	1.24	1.45	*1.59*	1.73	2.03
25	0.66	0.82	0.91	0.97	1.03	1.24	1.44	*1.58*	1.72	2.01
30	0.68	0.83	0.91	0.97	1.03	1.22	1.42	*1.56*	1.70	1.97
40	0.70	0.84	0.92	0.97	1.02	1.19	1.38	*1.51*	1.64	1.89
50	0.72	0.85	0.93	0.98	1.02	1.17	1.34	*1.46*	1.58	1.81
75	0.76	0.87	0.93	0.98	1.02	1.14	1.28	*1.38*	1.47	1.64
100	0.78	0.88	0.94	0.98	1.02	1.13	1.25	*1.33*	1.40	1.54
150	0.78	0.88	0.94	0.98	1.01	1.12	1.21	*1.27*	1.33	1.45
200	0.78	0.88	0.94	0.98	1.01	1.11	1.19	*1.25*	1.30	1.40

Extract of Wallingford Procedure Volume 1

RAINFALL DETAILS

M5-60	21	mm	*From Wallingford Procedure, Volume 3; Maps. Rainfall depth (M5-60 minutes)*
r	0.43		*From Wallingford Procedure, Volume 3; Maps. Ratio of M5-60 minutes to M5-two day rainfall*
CC	30%		*Climate change allowance*

DURATION (minutes)	Z1	M5-D (M5-60 x Z1) (mm)	Z2	M100-D (M5-D x Z2) (mm)	M100-D plus CC R (M5-D x Z2) (mm)
5	0.38	7.98	1.86	14.9	19.3
10	0.53	11.13	1.93	21.5	27.9
15	0.63	13.23	1.96	26.0	33.7
30	0.80	16.80	2.00	33.7	43.8
60	1.00	21.00	2.03	42.5	55.3
120	1.20	25.20	2.01	50.6	65.8
240	1.40	29.40	1.97	58.1	75.5
360	1.50	31.50	1.96	61.7	80.2
600	1.70	35.70	1.92	68.7	89.3
1440	2.10	44.10	1.86	81.9	106.5
2880	2.45	51.45	1.80	92.6	120.4

I - O = S
I = inflow
O = outflow
S = storage

I = A x R
A = impermeable contributing area
R = total rainfall

O = a_{s50} x *f* x D
a_{s50} = internal surface area of soakaway to 50% depth (excluding base)
f = soil infiltration rate
D = storm duration

CALCULATION SHEET

Project:	**60439696**		
Ref:			
Section:	**1**		
Made by:	**Lilian Gowans**	Date:	**21 October 2015**
Checked by:	**Jon Curry**	Date:	**26 October 2015**

Contributing Area	27000	m^2
Type of Storage	Lake	
Void Ratio	100	%
Length	N/A	m
Width	N/A	m
Depth	N/A	m
Number of	1	
Safety Factor	1	
Free Volume (Available Storage)	N/A	m^3
Permitted outflow	12.5	l/s/ha

DURATION (minutes)	INFLOW (A x R) (m^3)	OUTFLOW (a_{s50} x *f* x D) (m^3)	REQUIRED STORAGE (I - O) (m^3)
5	521	10	511
10	753	20	733
15	911	30	881
30	1182	61	1121
60	1493	122	1372
120	1776	243	1533
240	2038	486	1552
360	2165	729	1436
600	2411	1215	1196
1440	2875	2916	0
2880	3251	5832	0

Maximum Storage required **1552 m^3**

Project: 60439696
Ref:
Section: 1

Made by: Lilian Gowans Date: 21 October 2015
Checked by: Jon Curry Date: 26 October 2015
Approved By: Date:

DESIGN OF STORMWATER STORAGE FACILITY
Design of stormwater storage facility for section 3.

RAINFALL DETAILS

Wallingford Procedure
Table 6.2
Ratio Z2 (Relationship between rainfall of return period T (MT) and M5 - England and Wales)

M5 Rainfall (mm)	M1	M2	M3	M4	M5	M10	M20	*M30 (interpolated)*	M50	M100
5	0.62	0.79	0.89	0.97	1.02	1.19	1.36	*1.46*	1.56	1.79
10	0.61	0.79	0.90	0.97	1.03	1.22	1.41	*1.53*	1.65	1.91
15	0.62	0.80	0.90	0.97	1.03	1.24	1.44	*1.57*	1.70	1.99
20	0.64	0.81	0.90	0.97	1.03	1.24	1.45	*1.59*	1.73	2.03
25	0.66	0.82	0.91	0.97	1.03	1.24	1.44	*1.58*	1.72	2.01
30	0.68	0.83	0.91	0.97	1.03	1.22	1.42	*1.56*	1.70	1.97
40	0.70	0.84	0.92	0.97	1.02	1.19	1.38	*1.51*	1.64	1.89
50	0.72	0.85	0.93	0.98	1.02	1.17	1.34	*1.46*	1.58	1.81
75	0.76	0.87	0.93	0.98	1.02	1.14	1.28	*1.38*	1.47	1.64
100	0.78	0.88	0.94	0.98	1.02	1.13	1.25	*1.33*	1.40	1.54
150	0.78	0.88	0.94	0.98	1.01	1.12	1.21	*1.27*	1.33	1.45
200	0.78	0.88	0.94	0.98	1.01	1.11	1.19	*1.25*	1.30	1.40

Extract of Wallingford Procedure Volume 1

RAINFALL DETAILS

M5-60	21	mm	*From Wallingford Procedure, Volume 3; Maps. Rainfall depth (M5-60 minutes)*
r	0.43		*From Wallingford Procedure, Volume 3; Maps. Ratio of M5-60 minutes to M5-two day rainfall*
CC	30%		*Climate change allowance*

DURATION (minutes)	Z1	M5-D (M5-60 x Z1) (mm)	Z2	M100-D (M5-D x Z2) (mm)	M100-D plus CC R (M5-D x Z2) (mm)
5	0.38	7.98	1.86	14.9	19.3
10	0.53	11.13	1.93	21.5	27.9
15	0.63	13.23	1.96	26.0	33.7
30	0.80	16.80	2.00	33.7	43.8
60	1.00	21.00	2.03	42.5	55.3
120	1.20	25.20	2.01	50.6	65.8
240	1.40	29.40	1.97	58.1	75.5
360	1.50	31.50	1.96	61.7	80.2
600	1.70	35.70	1.92	68.7	89.3
1440	2.10	44.10	1.86	81.9	106.5
2880	2.45	51.45	1.80	92.6	120.4

I - O = S
I = inflow
O = outflow
S = storage

I = A x R
A = impermeable contributing area
R = total rainfall

O = a_{s50} x f x D
a_{s50} = internal surface area of soakaway to 50% depth (excluding base)
f = soil infiltration rate
D = storm duration

Project:	60439696
Ref:	
Section:	1

Made by:	Lilian Gowans	Date:	21 October 2015
Checked by:	Jon Curry	Date:	26 October 2015

Contributing Area	137400	m^2
Type of Storage	Lake	
Void Ratio	100	%
Length	N/A	m
Width	N/A	m
Depth	N/A	m
Number of	1	
Safety Factor	1	
Free Volume (Available Storage)	N/A	m^3
Permitted outflow	12.5	l/s/ha

DURATION (minutes)	INFLOW (A x R) (m^3)	OUTFLOW (a_{s50} x f x D) (m^3)	REQUIRED STORAGE (I - O) (m^3)
5	2653	52	2602
10	3833	103	3730
15	4636	155	4481
30	6015	309	5706
60	7600	618	6981
120	9040	1237	7804
240	10371	2473	7897
360	11017	3710	7307
600	12271	6183	6088
1440	14629	14839	0
2880	16543	29678	0

Maximum Storage required **7897 m^3**

Project: 60439696
Ref:
Section: 1

Made by: Lilian Gowans Date: 21 October 2015
Checked by: Jon Curry Date: 26 October 2015
Approved By: Date:

DESIGN OF STORMWATER STORAGE FACILITY
Design of stormwater storage facility for section 4.

RAINFALL DETAILS

Wallingford Procedure
Table 6.2
Ratio Z2 (Relationship between rainfall of return period T (MT) and M5 - England and Wales)

M5 Rainfall (mm)	M1	M2	M3	M4	M5	M10	M20	*M30 (interpolated)*	M50	M100
5	0.62	0.79	0.89	0.97	1.02	1.19	1.36	*1.46*	1.56	1.79
10	0.61	0.79	0.90	0.97	1.03	1.22	1.41	*1.53*	1.65	1.91
15	0.62	0.80	0.90	0.97	1.03	1.24	1.44	*1.57*	1.70	1.99
20	0.64	0.81	0.90	0.97	1.03	1.24	1.45	*1.59*	1.73	2.03
25	0.66	0.82	0.91	0.97	1.03	1.24	1.44	*1.58*	1.72	2.01
30	0.68	0.83	0.91	0.97	1.03	1.22	1.42	*1.56*	1.70	1.97
40	0.70	0.84	0.92	0.97	1.02	1.19	1.38	*1.51*	1.64	1.89
50	0.72	0.85	0.93	0.98	1.02	1.17	1.34	*1.46*	1.58	1.81
75	0.76	0.87	0.93	0.98	1.02	1.14	1.28	*1.38*	1.47	1.64
100	0.78	0.88	0.94	0.98	1.02	1.13	1.25	*1.33*	1.40	1.54
150	0.78	0.88	0.94	0.98	1.01	1.12	1.21	*1.27*	1.33	1.45
200	0.78	0.88	0.94	0.98	1.01	1.11	1.19	*1.25*	1.30	1.40

Extract of Wallingford Procedure Volume 1

RAINFALL DETAILS

M5-60	21	mm	*From Wallingford Procedure, Volume 3; Maps. Rainfall depth (M5-60 minutes)*
r	0.43		*From Wallingford Procedure, Volume 3; Maps. Ratio of M5-60 minutes to M5-two day rainfall*
CC	30%		*Climate change allowance*

DURATION (minutes)	Z1	M5-D (M5-60 x Z1) (mm)	Z2	M100-D (M5-D x Z2) (mm)	M100-D plus CC R (M5-D x Z2) (mm)
5	0.38	7.98	1.86	14.9	19.3
10	0.53	11.13	1.93	21.5	27.9
15	0.63	13.23	1.96	26.0	33.7
30	0.80	16.80	2.00	33.7	43.8
60	1.00	21.00	2.03	42.5	55.3
120	1.20	25.20	2.01	50.6	65.8
240	1.40	29.40	1.97	58.1	75.5
360	1.50	31.50	1.96	61.7	80.2
600	1.70	35.70	1.92	68.7	89.3
1440	2.10	44.10	1.86	81.9	106.5
2880	2.45	51.45	1.80	92.6	120.4

I - O = S
I = inflow
O = outflow
S = storage

I = A x R
A = impermeable contributing area
R = total rainfall

O = a_{s50} x f x D
a_{s50} = internal surface area of soakaway to 50% depth (excluding base)
f = soil infiltration rate
D = storm duration

Project:	60439696
Ref:	
Section:	1

Made by:	**Lilian Gowans**	Date:	**21 October 2015**
Checked by:	**Jon Curry**	Date:	**26 October 2015**

Contributing Area	32000	m^2
Type of Storage	Lake	
Void Ratio	100	%
Length	N/A	m
Width	N/A	m
Depth	N/A	m
Number of	1	
Safety Factor	1	
Free Volume (Available Storage)	N/A	m^3
Permitted outflow	12.5	l/s/ha

DURATION (minutes)	**INFLOW** (A x R) (m^3)	**OUTFLOW** (a_{s50} x *f* x D) (m^3)	**REQUIRED STORAGE** (I - O) (m^3)
5	618	12	606
10	893	24	869
15	1080	36	1044
30	1401	72	1329
60	1770	144	1626
120	2105	288	1817
240	2415	576	1839
360	2566	864	1702
600	2858	1440	1418
1440	3407	3456	0
2880	3853	6912	0

Maximum Storage required **1839 m^3**

Project: **60439696**
Ref:
Section: **1**

Made by: **Lilian Gowans** Date: **21 October 2015**
Checked by: **Jon Curry** Date: **26 October 2015**
Approved By: Date:

DESIGN OF STORMWATER STORAGE FACILITY
Design of stormwater storage facility for section 5.

RAINFALL DETAILS

Wallingford Procedure
Table 6.2
Ratio Z2 (Relationship between rainfall of return period T (MT) and M5 - England and Wales)

M5 Rainfall (mm)	**M1**	**M2**	**M3**	**M4**	**M5**	**M10**	**M20**	***M30*** *(interpolated)*	**M50**	**M100**
5	0.62	0.79	0.89	0.97	1.02	1.19	1.36	*1.46*	1.56	1.79
10	0.61	0.79	0.90	0.97	1.03	1.22	1.41	*1.53*	1.65	1.91
15	0.62	0.80	0.90	0.97	1.03	1.24	1.44	*1.57*	1.70	1.99
20	0.64	0.81	0.90	0.97	1.03	1.24	1.45	*1.59*	1.73	2.03
25	0.66	0.82	0.91	0.97	1.03	1.24	1.44	*1.58*	1.72	2.01
30	0.68	0.83	0.91	0.97	1.03	1.22	1.42	*1.56*	1.70	1.97
40	0.70	0.84	0.92	0.97	1.02	1.19	1.38	*1.51*	1.64	1.89
50	0.72	0.85	0.93	0.98	1.02	1.17	1.34	*1.46*	1.58	1.81
75	0.76	0.87	0.93	0.98	1.02	1.14	1.28	*1.38*	1.47	1.64
100	0.78	0.88	0.94	0.98	1.02	1.13	1.25	*1.33*	1.40	1.54
150	0.78	0.88	0.94	0.98	1.01	1.12	1.21	*1.27*	1.33	1.45
200	0.78	0.88	0.94	0.98	1.01	1.11	1.19	*1.25*	1.30	1.40

Extract of Wallingford Procedure Volume 1

RAINFALL DETAILS

M5-60	21	mm	*From Wallingford Procedure, Volume 3; Maps. Rainfall depth (M5-60 minutes)*
r	0.43		*From Wallingford Procedure, Volume 3; Maps. Ratio of M5-60 minutes to M5-two day rainfall*
CC	30%		*Climate change allowance*

DURATION (minutes)	**Z1**	**M5-D** (M5-60 x Z1) (mm)	**Z2**	**M100-D** (M5-D x Z2) (mm)	**M100-D plus CC** R (M5-D x Z2) (mm)
5	0.38	7.98	1.86	14.9	19.3
10	0.53	11.13	1.93	21.5	27.9
15	0.63	13.23	1.96	26.0	33.7
30	0.80	16.80	2.00	33.7	43.8
60	1.00	21.00	2.03	42.5	55.3
120	1.20	25.20	2.01	50.6	65.8
240	1.40	29.40	1.97	58.1	75.5
360	1.50	31.50	1.96	61.7	80.2
600	1.70	35.70	1.92	68.7	89.3
1440	2.10	44.10	1.86	81.9	106.5
2880	2.45	51.45	1.80	92.6	120.4

I - O = S
I = inflow
O = outflow
S = storage

I = A x R
A = impermeable contributing area
R = total rainfall

O = a_{s50} x *f* x D
a_{s50} = internal surface area of soakaway to 50% depth (excluding base)
f = soil infiltration rate
D = storm duration

Project:	**60439696**
Ref:	
Section:	**1**

Made by:	**Lilian Gowans**	Date:	**21 October 2015**
Checked by:	**Jon Curry**	Date:	**26 October 2015**

Contributing Area	45700	m^2
Type of Storage	Lake	
Void Ratio	100	%
Length	N/A	m
Width	N/A	m
Depth	N/A	m
Number of	1	
Safety Factor	1	
Free Volume (Available Storage)	N/A	m^3
Permitted outflow	12.5	l/s/ha

DURATION (minutes)	**INFLOW** (A x R) (m^3)	**OUTFLOW** (a_{s50} x *f* x D) (m^3)	**REQUIRED STORAGE** (I - O) (m^3)
5	883	17	865
10	1275	34	1241
15	1542	51	1490
30	2001	103	1898
60	2528	206	2322
120	3007	411	2596
240	3449	823	2627
360	3664	1234	2430
600	4082	2057	2025
1440	4866	4936	0
2880	5502	9871	0

Maximum Storage required **2627 m^3**

Project: 60439696
Ref:
Section: 1

Made by: Lilian Gowans — Date: 21 October 2015
Checked by: Jon Curry — Date: 26 October 2015
Approved By: — Date:

DESIGN OF STORMWATER STORAGE FACILITY
Design of stormwater storage facility for section 6.

RAINFALL DETAILS

Wallingford Procedure
Table 6.2
Ratio Z2 (Relationship between rainfall of return period T (MT) and M5 - England and Wales)

M5 Rainfall (mm)	M1	M2	M3	M4	M5	M10	M20	*M30 (interpolated)*	M50	M100
5	0.62	0.79	0.89	0.97	1.02	1.19	1.36	*1.46*	1.56	1.79
10	0.61	0.79	0.90	0.97	1.03	1.22	1.41	*1.53*	1.65	1.91
15	0.62	0.80	0.90	0.97	1.03	1.24	1.44	*1.57*	1.70	1.99
20	0.64	0.81	0.90	0.97	1.03	1.24	1.45	*1.59*	1.73	2.03
25	0.66	0.82	0.91	0.97	1.03	1.24	1.44	*1.58*	1.72	2.01
30	0.68	0.83	0.91	0.97	1.03	1.22	1.42	*1.56*	1.70	1.97
40	0.70	0.84	0.92	0.97	1.02	1.19	1.38	*1.51*	1.64	1.89
50	0.72	0.85	0.93	0.98	1.02	1.17	1.34	*1.46*	1.58	1.81
75	0.76	0.87	0.93	0.98	1.02	1.14	1.28	*1.38*	1.47	1.64
100	0.78	0.88	0.94	0.98	1.02	1.13	1.25	*1.33*	1.40	1.54
150	0.78	0.88	0.94	0.98	1.01	1.12	1.21	*1.27*	1.33	1.45
200	0.78	0.88	0.94	0.98	1.01	1.11	1.19	*1.25*	1.30	1.40

Extract of Wallingford Procedure Volume 1

RAINFALL DETAILS

M5-60	21	mm	*From Wallingford Procedure, Volume 3; Maps. Rainfall depth (M5-60 minutes)*
r	0.43		*From Wallingford Procedure, Volume 3; Maps. Ratio of M5-60 minutes to M5-two day rainfall*
CC	30%		*Climate change allowance*

DURATION (minutes)	Z1	M5-D (M5-60 x Z1) (mm)	Z2	M100-D (M5-D x Z2) (mm)	M100-D plus CC R (M5-D x Z2) (mm)
5	0.38	7.98	1.86	14.9	19.3
10	0.53	11.13	1.93	21.5	27.9
15	0.63	13.23	1.96	26.0	33.7
30	0.80	16.80	2.00	33.7	43.8
60	1.00	21.00	2.03	42.5	55.3
120	1.20	25.20	2.01	50.6	65.8
240	1.40	29.40	1.97	58.1	75.5
360	1.50	31.50	1.96	61.7	80.2
600	1.70	35.70	1.92	68.7	89.3
1440	2.10	44.10	1.86	81.9	106.5
2880	2.45	51.45	1.80	92.6	120.4

I - O = S
I = inflow
O = outflow
S = storage

I = A x R
A = impermeable contributing area
R = total rainfall

O = a_{s50} x f x D
a_{s50} = internal surface area of soakaway to 50% depth (excluding base)
f = soil infiltration rate
D = storm duration

Project:	60439696
Ref:	
Section:	1

Made by:	Lilian Gowans	Date:	21 October 2015
Checked by:	Jon Curry	Date:	26 October 2015

Contributing Area	167200	m^2
Type of Storage	Lake	
Void Ratio	100	%
Length	N/A	m
Width	N/A	m
Depth	N/A	m
Number of	1	
Safety Factor	1	
Free Volume (Available Storage)	N/A	m^3
Permitted outflow	12.5	l/s/ha

DURATION	INFLOW	OUTFLOW	REQUIRED STORAGE
	(A x R)	(a_{s50} x *f* x D)	(I - O)
(minutes)	(m^3)	(m^3)	(m^3)
5	3229	63	3166
10	4664	125	4539
15	5641	188	5453
30	7319	376	6943
60	9248	752	8495
120	11001	1505	9496
240	12620	3010	9610
360	13406	4514	8892
600	14933	7524	7409
1440	17802	18058	0
2880	20131	36115	0

Maximum Storage required **9610 m^3**

Project: 60439696
Ref:
Section: 1

Made by: Lilian Gowans Date: 21 October 2015
Checked by: Jon Curry Date: 26 October 2015
Approved By: Date:

DESIGN OF STORMWATER STORAGE FACILITY
Design of stormwater storage facility for section 7.

RAINFALL DETAILS

Wallingford Procedure
Table 6.2
Ratio Z2 (Relationship between rainfall of return period T (MT) and M5 - England and Wales)

M5 Rainfall (mm)	**M1**	**M2**	**M3**	**M4**	**M5**	**M10**	**M20**	***M30*** *(interpolated)*	**M50**	**M100**
5	0.62	0.79	0.89	0.97	1.02	1.19	1.36	*1.46*	1.56	1.79
10	0.61	0.79	0.90	0.97	1.03	1.22	1.41	*1.53*	1.65	1.91
15	0.62	0.80	0.90	0.97	1.03	1.24	1.44	*1.57*	1.70	1.99
20	0.64	0.81	0.90	0.97	1.03	1.24	1.45	*1.59*	1.73	2.03
25	0.66	0.82	0.91	0.97	1.03	1.24	1.44	*1.58*	1.72	2.01
30	0.68	0.83	0.91	0.97	1.03	1.22	1.42	*1.56*	1.70	1.97
40	0.70	0.84	0.92	0.97	1.02	1.19	1.38	*1.51*	1.64	1.89
50	0.72	0.85	0.93	0.98	1.02	1.17	1.34	*1.46*	1.58	1.81
75	0.76	0.87	0.93	0.98	1.02	1.14	1.28	*1.38*	1.47	1.64
100	0.78	0.88	0.94	0.98	1.02	1.13	1.25	*1.33*	1.40	1.54
150	0.78	0.88	0.94	0.98	1.01	1.12	1.21	*1.27*	1.33	1.45
200	0.78	0.88	0.94	0.98	1.01	1.11	1.19	*1.25*	1.30	1.40

Extract of Wallingford Procedure Volume 1

RAINFALL DETAILS

M5-60	21	mm	*From Wallingford Procedure, Volume 3; Maps. Rainfall depth (M5-60 minutes)*
r	0.43		*From Wallingford Procedure, Volume 3; Maps. Ratio of M5-60 minutes to M5-two day rainfall*
CC	30%		*Climate change allowance*

DURATION (minutes)	**Z1**	**M5-D** (M5-60 x Z1) (mm)	**Z2**	**M100-D** (M5-D x Z2) (mm)	**M100-D plus CC** R (M5-D x Z2) (mm)
5	0.38	7.98	1.86	14.9	19.3
10	0.53	11.13	1.93	21.5	27.9
15	0.63	13.23	1.96	26.0	33.7
30	0.80	16.80	2.00	33.7	43.8
60	1.00	21.00	2.03	42.5	55.3
120	1.20	25.20	2.01	50.6	65.8
240	1.40	29.40	1.97	58.1	75.5
360	1.50	31.50	1.96	61.7	80.2
600	1.70	35.70	1.92	68.7	89.3
1440	2.10	44.10	1.86	81.9	106.5
2880	2.45	51.45	1.80	92.6	120.4

I - O = S
I = inflow
O = outflow
S = storage

I = A x R
A = impermeable contributing area
R = total rainfall

O = a_{s50} x f x D
a_{s50} = internal surface area of soakaway to 50% depth (excluding base)
f = soil infiltration rate
D = storm duration

Project:	**60439696**
Ref:	
Section:	**1**

Made by:	**Lilian Gowans**	Date:	**21 October 2015**
Checked by:	**Jon Curry**	Date:	**26 October 2015**

Contributing Area	106800	m^2
Type of Storage	Lake	
Void Ratio	100	%
Length	N/A	m
Width	N/A	m
Depth	N/A	m
Number of	1	
Safety Factor	1	
Free Volume (Available Storage)	N/A	m^3
Permitted outflow	12.5	l/s/ha

DURATION (minutes)	**INFLOW** (A x R) (m^3)	**OUTFLOW** (a_{s50} x *f* x D) (m^3)	**REQUIRED STORAGE** (I - O) (m^3)
5	2062	40	2022
10	2979	80	2899
15	3603	120	3483
30	4675	240	4435
60	5907	481	5426
120	7027	961	6066
240	8061	1922	6139
360	8563	2884	5680
600	9538	4806	4732
1440	11371	11534	0
2880	12859	23069	0

Maximum Storage required **6139 m^3**

Project: 60439696
Ref:
Section: 1

Made by: Lilian Gowans Date: 21 October 2015
Checked by: Jon Curry Date: 26 October 2015
Approved By: Date:

DESIGN OF STORMWATER STORAGE FACILITY

Design of stormwater storage facility for section 8.

RAINFALL DETAILS

Wallingford Procedure
Table 6.2
Ratio Z2 (Relationship between rainfall of return period T (MT) and M5 - England and Wales)

M5 Rainfall (mm)	M1	M2	M3	M4	M5	M10	M20	*M30 (interpolated)*	M50	M100
5	0.62	0.79	0.89	0.97	1.02	1.19	1.36	*1.46*	1.56	1.79
10	0.61	0.79	0.90	0.97	1.03	1.22	1.41	*1.53*	1.65	1.91
15	0.62	0.80	0.90	0.97	1.03	1.24	1.44	*1.57*	1.70	1.99
20	0.64	0.81	0.90	0.97	1.03	1.24	1.45	*1.59*	1.73	2.03
25	0.66	0.82	0.91	0.97	1.03	1.24	1.44	*1.58*	1.72	2.01
30	0.68	0.83	0.91	0.97	1.03	1.22	1.42	*1.56*	1.70	1.97
40	0.70	0.84	0.92	0.97	1.02	1.19	1.38	*1.51*	1.64	1.89
50	0.72	0.85	0.93	0.98	1.02	1.17	1.34	*1.46*	1.58	1.81
75	0.76	0.87	0.93	0.98	1.02	1.14	1.28	*1.38*	1.47	1.64
100	0.78	0.88	0.94	0.98	1.02	1.13	1.25	*1.33*	1.40	1.54
150	0.78	0.88	0.94	0.98	1.01	1.12	1.21	*1.27*	1.33	1.45
200	0.78	0.88	0.94	0.98	1.01	1.11	1.19	*1.25*	1.30	1.40

Extract of Wallingford Procedure Volume 1

RAINFALL DETAILS

M5-60	21	mm	*From Wallingford Procedure, Volume 3; Maps. Rainfall depth (M5-60 minutes)*
r	0.43		*From Wallingford Procedure, Volume 3; Maps. Ratio of M5-60 minutes to M5-two day rainfall*
CC	30%		*Climate change allowance*

DURATION (minutes)	Z1	M5-D (M5-60 x Z1) (mm)	Z2	M100-D (M5-D x Z2) (mm)	M100-D plus CC R (M5-D x Z2) (mm)
5	0.38	7.98	1.86	14.9	19.3
10	0.53	11.13	1.93	21.5	27.9
15	0.63	13.23	1.96	26.0	33.7
30	0.80	16.80	2.00	33.7	43.8
60	1.00	21.00	2.03	42.5	55.3
120	1.20	25.20	2.01	50.6	65.8
240	1.40	29.40	1.97	58.1	75.5
360	1.50	31.50	1.96	61.7	80.2
600	1.70	35.70	1.92	68.7	89.3
1440	2.10	44.10	1.86	81.9	106.5
2880	2.45	51.45	1.80	92.6	120.4

I - O = S
I = inflow
O = outflow
S = storage

I = A x R
A = impermeable contributing area
R = total rainfall

O = a_{s50} x *f* x D
a_{s50} = internal surface area of soakaway to 50% depth (excluding base)
f = soil infiltration rate
D = storm duration

AECOM **CALCULATION SHEET**

Project:	**60439696**		
Ref:			
Section:	**1**		
Made by:	**Lilian Gowans**	Date:	**21 October 2015**
Checked by:	**Jon Curry**	Date:	**26 October 2015**

Contributing Area	32200	m^2
Type of Storage	Lake	
Void Ratio	100	%
Length	N/A	m
Width	N/A	m
Depth	N/A	m
Number of	1	
Safety Factor	1	
Free Volume (Available Storage)	N/A	m^3
Permitted outflow	12.5	l/s/ha

DURATION (minutes)	**INFLOW** (A x R) (m^3)	**OUTFLOW** (a_{s50} x f x D) (m^3)	**REQUIRED STORAGE** (I - O) (m^3)
5	622	12	610
10	898	24	874
15	1086	36	1050
30	1410	72	1337
60	1781	145	1636
120	2119	290	1829
240	2430	580	1851
360	2582	869	1712
600	2876	1449	1427
1440	3428	3478	0
2880	3877	6955	0

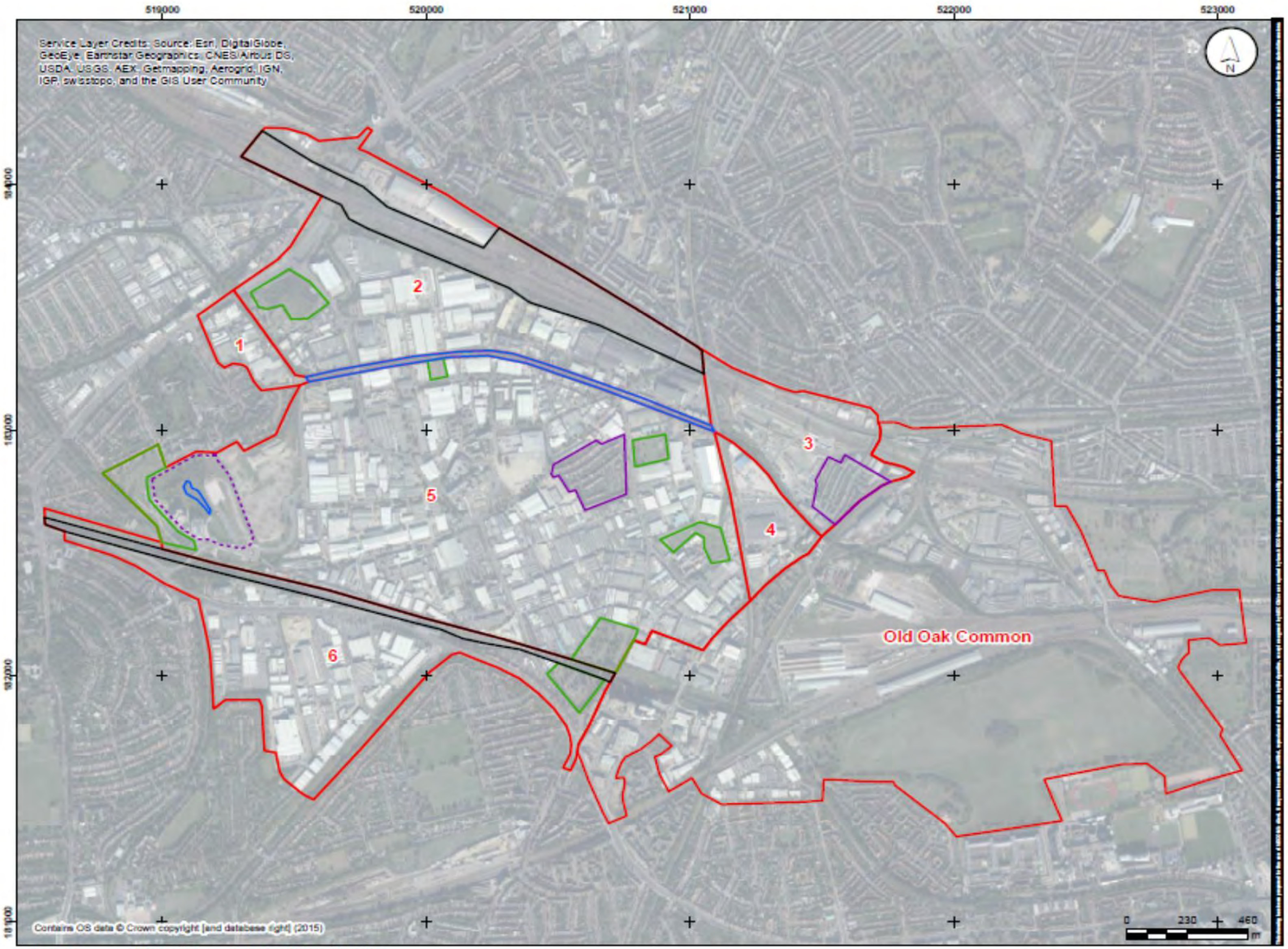
Maximum Storage required **1851 m^3**

Total Storage Needed for Old Oak

Plot	Maximum Storage Required (m^3)
1	1937
2	1552
3	7897
4	1839
5	2627
6	9610
7	6139
8	1851
Total	33452

Sections

Royal Parks	Plots (m²)		Easting/Northing	Lat/Lon
	1	75,143.28	519194, 183419	51.537099,-0.282813
	2	986,702.09	519489, 183674	51.539328,-0.278475
	3	274,061.19	521434, 182969	51.532578,-0.250687
	4	115,942.43	521284, 182669	51.529914,-0.252952
	5	1,967,278.15	520834, 182887	51.531969,-0.259361
	6	703,181.41	520306, 182047	51.524533,-0.267256



AECOM

PROJECT

OLD OAK COMMON AND ROYAL PARK DEVELOPMENT

CLIENT

OLD OAK COMMON DEVELOPMENT CORPORATION

CONSULTANT

AECOM Limited
1 Callaghan Square
Cardiff, CF10 5BT
+44 (0)29 2067 4600 tel
www.aecom.com

LEGEND

- Catchment
- Green Space
- Waterbody
- Rail Track
- Residential
- Proposed Residential

ISSUE/REVISION

A	11/09/2015	ISSUED FOR INFORMATION
I/R	DATE	DESCRIPTION

KEY PLAN

CONTRACT NUMBER

XXXXXXXXXX

SHEET TITLE

Figure 4 - Park Royal Sub-Catchments

Scale at A3: 1:13,500

SHEET NUMBER

150911_ParkRoyalSubCatchments v1

Project: **60439696**
Ref:
Section: **1**

Made by: **Lilian Gowans** Date: **21 October 2015**
Checked by: **Jon Curry** Date: **26 October 2015**
Approved By: Date:

DESIGN OF STORMWATER STORAGE FACILITY

Design of stormwater storage facility for section 1.

RAINFALL DETAILS

Wallingford Procedure
Table 6.2
Ratio Z2 (Relationship between rainfall of return period T (MT) and M5 - England and Wales)

M5 Rainfall (mm)	**M1**	**M2**	**M3**	**M4**	**M5**	**M10**	**M20**	***M30*** *(interpolated)*	**M50**	**M100**
5	0.62	0.79	0.89	0.97	1.02	1.19	1.36	*1.46*	1.56	1.79
10	0.61	0.79	0.90	0.97	1.03	1.22	1.41	*1.53*	1.65	1.91
15	0.62	0.80	0.90	0.97	1.03	1.24	1.44	*1.57*	1.70	1.99
20	0.64	0.81	0.90	0.97	1.03	1.24	1.45	*1.59*	1.73	2.03
25	0.66	0.82	0.91	0.97	1.03	1.24	1.44	*1.58*	1.72	2.01
30	0.68	0.83	0.91	0.97	1.03	1.22	1.42	*1.56*	1.70	1.97
40	0.70	0.84	0.92	0.97	1.02	1.19	1.38	*1.51*	1.64	1.89
50	0.72	0.85	0.93	0.98	1.02	1.17	1.34	*1.46*	1.58	1.81
75	0.76	0.87	0.93	0.98	1.02	1.14	1.28	*1.38*	1.47	1.64
100	0.78	0.88	0.94	0.98	1.02	1.13	1.25	*1.33*	1.40	1.54
150	0.78	0.88	0.94	0.98	1.01	1.12	1.21	*1.27*	1.33	1.45
200	0.78	0.88	0.94	0.98	1.01	1.11	1.19	*1.25*	1.30	1.40

Extract of Wallingford Procedure Volume 1

RAINFALL DETAILS

M5-60	21	mm	*From Wallingford Procedure, Volume 3; Maps. Rainfall depth (M5-60 minutes)*
r	0.43		*From Wallingford Procedure, Volume 3; Maps. Ratio of M5-60 minutes to M5-two day rainfall*
CC	30%		*Climate change allowance*

DURATION (minutes)	**Z1**	**M5-D** (M5-60 x Z1) (mm)	**Z2**	**M100-D** (M5-D x Z2) (mm)	**M100-D plus CC** R (M5-D x Z2) (mm)
5	0.38	7.98	1.86	14.9	19.3
10	0.53	11.13	1.93	21.5	27.9
15	0.63	13.23	1.96	26.0	33.7
30	0.80	16.80	2.00	33.7	43.8
60	1.00	21.00	2.03	42.5	55.3
120	1.20	25.20	2.01	50.6	65.8
240	1.40	29.40	1.97	58.1	75.5
360	1.50	31.50	1.96	61.7	80.2
600	1.70	35.70	1.92	68.7	89.3
1440	2.10	44.10	1.86	81.9	106.5
2880	2.45	51.45	1.80	92.6	120.4

I - O = S
I = inflow
O = outflow
S = storage

I = A x R
A = impermeable contributing area
R = total rainfall

$O = a_{s50} \times f \times D$

a_{s50} = internal surface area of soakaway to 50% depth (excluding base)
f = soil infiltration rate
D = storm duration

Contributing Area	75,143	m^2
Type of Storage	Lake	
Void Ratio	100	%
Length	N/A	m
Width	N/A	m
Depth	N/A	m
Number of	1	
Safety Factor	1	
Free Volume (Available Storage)	N/A	m^3
Permitted outflow	12.5	l/s/ha

DURATION	**INFLOW**	**OUTFLOW**	**REQUIRED STORAGE**
	(A x R)	(a_{s50} x *f* x D)	(I - O)
(minutes)	(m^3)	(m^3)	(m^3)
5	1451	28	1423
10	2096	56	2040
15	2535	85	2451
30	3289	169	3120
60	4156	338	3818
120	4944	676	4268
240	5672	1353	4319
360	6025	2029	3996
600	6711	3381	3330
1440	8001	8115	0
2880	9047	16231	0

Maximum Storage required **4319 m^3**

Project: **60439696**
Ref:
Section: **1**

Made by: **Lilian Gowans** Date: **21 October 2015**
Checked by: **Jon Curry** Date: **26 October 2015**
Approved By: Date:

DESIGN OF STORMWATER STORAGE FACILITY
Design of stormwater storage facility for section 1.

RAINFALL DETAILS

Wallingford Procedure
Table 6.2
Ratio Z2 (Relationship between rainfall of return period T (MT) and M5 - England and Wales)

M5 Rainfall (mm)	**M1**	**M2**	**M3**	**M4**	**M5**	**M10**	**M20**	***M30*** *(interpolated)*	**M50**	**M100**
5	0.62	0.79	0.89	0.97	1.02	1.19	1.36	*1.46*	1.56	1.79
10	0.61	0.79	0.90	0.97	1.03	1.22	1.41	*1.53*	1.65	1.91
15	0.62	0.80	0.90	0.97	1.03	1.24	1.44	*1.57*	1.70	1.99
20	0.64	0.81	0.90	0.97	1.03	1.24	1.45	*1.59*	1.73	2.03
25	0.66	0.82	0.91	0.97	1.03	1.24	1.44	*1.58*	1.72	2.01
30	0.68	0.83	0.91	0.97	1.03	1.22	1.42	*1.56*	1.70	1.97
40	0.70	0.84	0.92	0.97	1.02	1.19	1.38	*1.51*	1.64	1.89
50	0.72	0.85	0.93	0.98	1.02	1.17	1.34	*1.46*	1.58	1.81
75	0.76	0.87	0.93	0.98	1.02	1.14	1.28	*1.38*	1.47	1.64
100	0.78	0.88	0.94	0.98	1.02	1.13	1.25	*1.33*	1.40	1.54
150	0.78	0.88	0.94	0.98	1.01	1.12	1.21	*1.27*	1.33	1.45
200	0.78	0.88	0.94	0.98	1.01	1.11	1.19	*1.25*	1.30	1.40

Extract of Wallingford Procedure Volume 1

v

M5-60	21 mm	*From Wallingford Procedure, Volume 3; Maps. Rainfall depth (M5-60 minutes)*
r	0.43	*From Wallingford Procedure, Volume 3; Maps. Ratio of M5-60 minutes to M5-two day rainfall*
CC	30%	*Climate change allowance*

DURATION (minutes)	**Z1**	**M5-D** (M5-60 x Z1) (mm)	**Z2**	**M100-D** (M5-D x Z2) (mm)	**M100-D plus CC** R (M5-D x Z2) (mm)
5	0.38	7.98	1.86	14.9	19.3
10	0.53	11.13	1.93	21.5	27.9
15	0.63	13.23	1.96	26.0	33.7
30	0.80	16.80	2.00	33.7	43.8
60	1.00	21.00	2.03	42.5	55.3
120	1.20	25.20	2.01	50.6	65.8
240	1.40	29.40	1.97	58.1	75.5
360	1.50	31.50	1.96	61.7	80.2
600	1.70	35.70	1.92	68.7	89.3
1440	2.10	44.10	1.86	81.9	106.5
2880	2.45	51.45	1.80	92.6	120.4

I - O = S
I = inflow
O = outflow
S = storage

I = A x R
A = impermeable contributing area
R = total rainfall

O = a_{s50} x f x D
a_{s50} = internal surface area of soakaway to 50% depth (excluding base)
f = soil infiltration rate
D = storm duration

Contributing Area	986,702	m^2
Type of Storage	Lake	
Void Ratio	100	%
Length	N/A	m
Width	N/A	m
Depth	N/A	m
Number of	1	
Safety Factor	1	
Free Volume (Available Storage)	N/A	m^3
Permitted outflow	12.5	l/s/ha

DURATION	**INFLOW**	**OUTFLOW**	**REQUIRED STORAGE**
	(A x R)	(a_{s50} x *f* x D)	(I - O)
(minutes)	(m^3)	(m^3)	(m^3)
5	19055	370	18685
10	27526	740	26786
15	33290	1110	32180
30	43194	2220	40974
60	54574	4440	50134
120	64920	8880	56040
240	74473	17761	56713
360	79114	26641	52473
600	88124	44402	43722
1440	105057	106564	0
2880	118801	213128	0

Maximum Storage required **56713 m^3**

Project: **60439696**
Ref:
Section: **1**

Made by: **Lilian Gowans** Date: **21 October 2015**
Checked by: **Jon Curry** Date: **26 October 2015**
Approved By: Date:

DESIGN OF STORMWATER STORAGE FACILITY
Design of stormwater storage facility for section 1.

RAINFALL DETAILS

Wallingford Procedure
Table 6.2
Ratio Z2 (Relationship between rainfall of return period T (MT) and M5 - England and Wales)

M5 Rainfall (mm)	M1	M2	M3	M4	M5	M10	M20	*M30 (interpolated)*	M50	M100
5	0.62	0.79	0.89	0.97	1.02	1.19	1.36	*1.46*	1.56	1.79
10	0.61	0.79	0.90	0.97	1.03	1.22	1.41	*1.53*	1.65	1.91
15	0.62	0.80	0.90	0.97	1.03	1.24	1.44	*1.57*	1.70	1.99
20	0.64	0.81	0.90	0.97	1.03	1.24	1.45	*1.59*	1.73	2.03
25	0.66	0.82	0.91	0.97	1.03	1.24	1.44	*1.58*	1.72	2.01
30	0.68	0.83	0.91	0.97	1.03	1.22	1.42	*1.56*	1.70	1.97
40	0.70	0.84	0.92	0.97	1.02	1.19	1.38	*1.51*	1.64	1.89
50	0.72	0.85	0.93	0.98	1.02	1.17	1.34	*1.46*	1.58	1.81
75	0.76	0.87	0.93	0.98	1.02	1.14	1.28	*1.38*	1.47	1.64
100	0.78	0.88	0.94	0.98	1.02	1.13	1.25	*1.33*	1.40	1.54
150	0.78	0.88	0.94	0.98	1.01	1.12	1.21	*1.27*	1.33	1.45
200	0.78	0.88	0.94	0.98	1.01	1.11	1.19	*1.25*	1.30	1.40

Extract of Wallingford Procedure Volume 1

RAINFALL DETAILS

M5-60	21	mm	*From Wallingford Procedure, Volume 3; Maps. Rainfall depth (M5-60 minutes)*
r	0.43		*From Wallingford Procedure, Volume 3; Maps. Ratio of M5-60 minutes to M5-two day rainfall*
CC	30%		*Climate change allowance*

DURATION (minutes)	**Z1**	**M5-D** (M5-60 x Z1) (mm)	**Z2**	**M100-D** (M5-D x Z2) (mm)	**M100-D plus CC** R (M5-D x Z2) (mm)
5	0.38	7.98	1.86	14.9	19.3
10	0.53	11.13	1.93	21.5	27.9
15	0.63	13.23	1.96	26.0	33.7
30	0.80	16.80	2.00	33.7	43.8
60	1.00	21.00	2.03	42.5	55.3
120	1.20	25.20	2.01	50.6	65.8
240	1.40	29.40	1.97	58.1	75.5
360	1.50	31.50	1.96	61.7	80.2
600	1.70	35.70	1.92	68.7	89.3
1440	2.10	44.10	1.86	81.9	106.5
2880	2.45	51.45	1.80	92.6	120.4

I - O = S
I = inflow
O = outflow
S = storage

I = A x R
A = impermeable contributing area
R = total rainfall

O = a_{s50} x f x D
a_{s50} = internal surface area of soakaway to 50% depth (excluding base)
f = soil infiltration rate
D = storm duration

Contributing Area	274,061	m^2
Type of Storage	Lake	
Void Ratio	100	%
Length	N/A	m
Width	N/A	m
Depth	N/A	m
Number of	1	
Safety Factor	1	
Free Volume (Available Storage)	N/A	m^3
Permitted outflow	12.5	l/s/ha

DURATION	INFLOW	OUTFLOW	REQUIRED STORAGE
	(A x R)	(a_{s50} x *f* x D)	(I - O)
(minutes)	(m^3)	(m^3)	(m^3)
5	5293	103	5190
10	7646	206	7440
15	9247	308	8938
30	11997	617	11381
60	15158	1233	13925
120	18032	2467	15565
240	20685	4933	15752
360	21974	7400	14575
600	24477	12333	12144
1440	29180	29599	0
2880	32998	59197	0

Maximum Storage required **15752 m^3**

Project: **60439696**
Ref:
Section: **1**

Made by: **Lilian Gowans** Date: **21 October 2015**
Checked by: **Jon Curry** Date: **26 October 2015**
Approved By: Date:

DESIGN OF STORMWATER STORAGE FACILITY
Design of stormwater storage facility for section 1.

RAINFALL DETAILS

Wallingford Procedure
Table 6.2
Ratio Z2 (Relationship between rainfall of return period T (MT) and M5 - England and Wales)

M5 Rainfall (mm)	**M1**	**M2**	**M3**	**M4**	**M5**	**M10**	**M20**	***M30*** *(interpolated)*	**M50**	**M100**
5	0.62	0.79	0.89	0.97	1.02	1.19	1.36	*1.46*	1.56	1.79
10	0.61	0.79	0.90	0.97	1.03	1.22	1.41	*1.53*	1.65	1.91
15	0.62	0.80	0.90	0.97	1.03	1.24	1.44	*1.57*	1.70	1.99
20	0.64	0.81	0.90	0.97	1.03	1.24	1.45	*1.59*	1.73	2.03
25	0.66	0.82	0.91	0.97	1.03	1.24	1.44	*1.58*	1.72	2.01
30	0.68	0.83	0.91	0.97	1.03	1.22	1.42	*1.56*	1.70	1.97
40	0.70	0.84	0.92	0.97	1.02	1.19	1.38	*1.51*	1.64	1.89
50	0.72	0.85	0.93	0.98	1.02	1.17	1.34	*1.46*	1.58	1.81
75	0.76	0.87	0.93	0.98	1.02	1.14	1.28	*1.38*	1.47	1.64
100	0.78	0.88	0.94	0.98	1.02	1.13	1.25	*1.33*	1.40	1.54
150	0.78	0.88	0.94	0.98	1.01	1.12	1.21	*1.27*	1.33	1.45
200	0.78	0.88	0.94	0.98	1.01	1.11	1.19	*1.25*	1.30	1.40

Extract of Wallingford Procedure Volume 1

RAINFALL DETAILS

M5-60	21	mm	*From Wallingford Procedure, Volume 3; Maps. Rainfall depth (M5-60 minutes)*
r	0.43		*From Wallingford Procedure, Volume 3; Maps. Ratio of M5-60 minutes to M5-two day rainfall*
CC	30%		*Climate change allowance*

DURATION (minutes)	**Z1**	**M5-D** (M5-60 x Z1) (mm)	**Z2**	**M100-D** (M5-D x Z2) (mm)	**M100-D plus CC** R (M5-D x Z2) (mm)
5	0.38	7.98	1.86	14.9	19.3
10	0.53	11.13	1.93	21.5	27.9
15	0.63	13.23	1.96	26.0	33.7
30	0.80	16.80	2.00	33.7	43.8
60	1.00	21.00	2.03	42.5	55.3
120	1.20	25.20	2.01	50.6	65.8
240	1.40	29.40	1.97	58.1	75.5
360	1.50	31.50	1.96	61.7	80.2
600	1.70	35.70	1.92	68.7	89.3
1440	2.10	44.10	1.86	81.9	106.5
2880	2.45	51.45	1.80	92.6	120.4

I - O = S
I = inflow
O = outflow
S = storage

I = A x R
A = impermeable contributing area
R = total rainfall

O = a_{s50} x f x D
a_{s50} = internal surface area of soakaway to 50% depth (excluding base)
f = soil infiltration rate
D = storm duration

Contributing Area	115,942	m^2
Type of Storage	Lake	
Void Ratio	100	%
Length	N/A	m
Width	N/A	m
Depth	N/A	m
Number of	1	
Safety Factor	1	
Free Volume (Available Storage)	N/A	m^3
Permitted outflow	12.5	l/s/ha

DURATION	**INFLOW**	**OUTFLOW**	**REQUIRED STORAGE**
	(A x R)	(a_{s50} x *f* x D)	(I - O)
(minutes)	(m^3)	(m^3)	(m^3)
5	2239	43	2196
10	3234	87	3148
15	3912	130	3781
30	5076	261	4815
60	6413	522	5891
120	7628	1043	6585
240	8751	2087	6664
360	9296	3130	6166
600	10355	5217	5138
1440	12345	12522	0
2880	13960	25044	0

Maximum Storage required **6664 m^3**

Project: **60439696**
Ref:
Section: **1**

Made by: **Lilian Gowans** Date: **21 October 2015**
Checked by: **Jon Curry** Date: **26 October 2015**
Approved By: Date:

DESIGN OF STORMWATER STORAGE FACILITY
Design of stormwater storage facility for section 1.

RAINFALL DETAILS

Wallingford Procedure
Table 6.2
Ratio Z2 (Relationship between rainfall of return period T (MT) and M5 - England and Wales)

M5 Rainfall (mm)	**M1**	**M2**	**M3**	**M4**	**M5**	**M10**	**M20**	***M30*** *(interpolated)*	**M50**	**M100**
5	0.62	0.79	0.89	0.97	1.02	1.19	1.36	*1.46*	1.56	1.79
10	0.61	0.79	0.90	0.97	1.03	1.22	1.41	*1.53*	1.65	1.91
15	0.62	0.80	0.90	0.97	1.03	1.24	1.44	*1.57*	1.70	1.99
20	0.64	0.81	0.90	0.97	1.03	1.24	1.45	*1.59*	1.73	2.03
25	0.66	0.82	0.91	0.97	1.03	1.24	1.44	*1.58*	1.72	2.01
30	0.68	0.83	0.91	0.97	1.03	1.22	1.42	*1.56*	1.70	1.97
40	0.70	0.84	0.92	0.97	1.02	1.19	1.38	*1.51*	1.64	1.89
50	0.72	0.85	0.93	0.98	1.02	1.17	1.34	*1.46*	1.58	1.81
75	0.76	0.87	0.93	0.98	1.02	1.14	1.28	*1.38*	1.47	1.64
100	0.78	0.88	0.94	0.98	1.02	1.13	1.25	*1.33*	1.40	1.54
150	0.78	0.88	0.94	0.98	1.01	1.12	1.21	*1.27*	1.33	1.45
200	0.78	0.88	0.94	0.98	1.01	1.11	1.19	*1.25*	1.30	1.40

Extract of Wallingford Procedure Volume 1

RAINFALL DETAILS

M5-60	21	mm	*From Wallingford Procedure, Volume 3; Maps. Rainfall depth (M5-60 minutes)*
r	0.43		*From Wallingford Procedure, Volume 3; Maps. Ratio of M5-60 minutes to M5-two day rainfall*
CC	30%		*Climate change allowance*

DURATION (minutes)	**Z1**	**M5-D** (M5-60 x Z1) (mm)	**Z2**	**M100-D** (M5-D x Z2) (mm)	**M100-D plus CC** R (M5-D x Z2) (mm)
5	0.38	7.98	1.86	14.9	19.3
10	0.53	11.13	1.93	21.5	27.9
15	0.63	13.23	1.96	26.0	33.7
30	0.80	16.80	2.00	33.7	43.8
60	1.00	21.00	2.03	42.5	55.3
120	1.20	25.20	2.01	50.6	65.8
240	1.40	29.40	1.97	58.1	75.5
360	1.50	31.50	1.96	61.7	80.2
600	1.70	35.70	1.92	68.7	89.3
1440	2.10	44.10	1.86	81.9	106.5
2880	2.45	51.45	1.80	92.6	120.4

I - O = S
I = inflow
O = outflow
S = storage

I = A x R
A = impermeable contributing area
R = total rainfall

O = a_{s50} x f x D
a_{s50} = internal surface area of soakaway to 50% depth (excluding base)
f = soil infiltration rate
D = storm duration

Contributing Area	1,967,278	m^2
Type of Storage	Lake	
Void Ratio	100	%
Length	N/A	m
Width	N/A	m
Depth	N/A	m
Number of	1	
Safety Factor	1	
Free Volume (Available Storage)	N/A	m^3
Permitted outflow	12.5	l/s/ha

DURATION (minutes)	**INFLOW** (A x R) (m^3)	**OUTFLOW** (a_{s50} x f x D) (m^3)	**REQUIRED STORAGE** (I - O) (m^3)
5	37991	738	37253
10	54882	1475	53406
15	66374	2213	64161
30	86120	4426	81693
60	108810	8853	99957
120	129437	17706	111732
240	148484	35411	113073
360	157737	53117	104620
600	175700	88528	87173
1440	209463	212466	0
2880	236865	424932	0

Maximum Storage required **113073 m^3**

Project:	**60439696**
Ref:	
Section:	**1**

Made by:	**Lilian Gowans**	Date:	**21 October 2015**
Checked by:	**Jon Curry**	Date:	**26 October 2015**
Approved By:		Date:	

DESIGN OF STORMWATER STORAGE FACILITY

Design of stormwater storage facility for section 1.

RAINFALL DETAILS

Wallingford Procedure
Table 6.2
Ratio Z2 (Relationship between rainfall of return period T (MT) and M5 - England and Wales)

M5 Rainfall (mm)	**M1**	**M2**	**M3**	**M4**	**M5**	**M10**	**M20**	***M30*** *(interpolated)*	**M50**	**M100**
5	0.62	0.79	0.89	0.97	1.02	1.19	1.36	*1.46*	1.56	1.79
10	0.61	0.79	0.90	0.97	1.03	1.22	1.41	*1.53*	1.65	1.91
15	0.62	0.80	0.90	0.97	1.03	1.24	1.44	*1.57*	1.70	1.99
20	0.64	0.81	0.90	0.97	1.03	1.24	1.45	*1.59*	1.73	2.03
25	0.66	0.82	0.91	0.97	1.03	1.24	1.44	*1.58*	1.72	2.01
30	0.68	0.83	0.91	0.97	1.03	1.22	1.42	*1.56*	1.70	1.97
40	0.70	0.84	0.92	0.97	1.02	1.19	1.38	*1.51*	1.64	1.89
50	0.72	0.85	0.93	0.98	1.02	1.17	1.34	*1.46*	1.58	1.81
75	0.76	0.87	0.93	0.98	1.02	1.14	1.28	*1.38*	1.47	1.64
100	0.78	0.88	0.94	0.98	1.02	1.13	1.25	*1.33*	1.40	1.54
150	0.78	0.88	0.94	0.98	1.01	1.12	1.21	*1.27*	1.33	1.45
200	0.78	0.88	0.94	0.98	1.01	1.11	1.19	*1.25*	1.30	1.40

Extract of Wallingford Procedure Volume 1

RAINFALL DETAILS

M5-60	21	mm	*From Wallingford Procedure, Volume 3; Maps. Rainfall depth (M5-60 minutes)*
r	0.43		*From Wallingford Procedure, Volume 3; Maps. Ratio of M5-60 minutes to M5-two day rainfall*
CC	30%		*Climate change allowance*

DURATION (minutes)	**Z1**	**M5-D** (M5-60 x Z1) (mm)	**Z2**	**M100-D** (M5-D x Z2) (mm)	**M100-D plus CC** R (M5-D x Z2) (mm)
5	0.38	7.98	1.86	14.9	19.3
10	0.53	11.13	1.93	21.5	27.9
15	0.63	13.23	1.96	26.0	33.7
30	0.80	16.80	2.00	33.7	43.8
60	1.00	21.00	2.03	42.5	55.3
120	1.20	25.20	2.01	50.6	65.8
240	1.40	29.40	1.97	58.1	75.5
360	1.50	31.50	1.96	61.7	80.2
600	1.70	35.70	1.92	68.7	89.3
1440	2.10	44.10	1.86	81.9	106.5
2880	2.45	51.45	1.80	92.6	120.4

I - O = S
I = inflow
O = outflow
S = storage

I = A x R
A = impermeable contributing area
R = total rainfall

O = a_{s50} x *f* x D
a_{s50} = internal surface area of soakaway to 50% depth (excluding base)
f = soil infiltration rate
D = storm duration

Contributing Area	703,181	m^2
Type of Storage	Lake	
Void Ratio	95	%
Length	N/A	m
Width	N/A	m
Depth	N/A	m
Number of	1	
Safety Factor	1	
Free Volume (Available Storage)	N/A	m^3
Permitted outflow	12.5	l/s/ha

DURATION	**INFLOW**	**OUTFLOW**	**REQUIRED STORAGE**
	(A x R)	(a_{s50} x *f* x D)	(I - O)
(minutes)	(m^3)	(m^3)	(m^3)
5	13579	264	13316
10	19617	527	19090
15	23725	791	22934
30	30783	1582	29200
60	38893	3164	35729
120	46266	6329	39937
240	53074	12657	40417
360	56381	18986	37395
600	62802	31643	31159
1440	74870	75944	0
2880	84665	151887	0

Maximum Storage required **40417 m^3**

Total Storage Needed for Old Oak

Plot	Maximum Storage Required (m^3)
1	4319
2	56713
3	15752
4	6664
5	113073
6	40417
Total	236937