

OPDC
OLD OAK AND
PARK ROYAL
DEVELOPMENT
CORPORATION

Integrated Water Management Strategy

LOCAL PLAN SUPPORTING STUDY

2017



MAYOR OF LONDON

28. Integrated Water Management Strategy

Document Title	Integrated Water Management Strategy
Lead Author	AECOM
Purpose of the Study	To establish a framework that will define how water and wastewater should be managed in a sustainable manner within the Old Oak and Park Royal area.
Key outputs	<ul style="list-style-type: none"> • Identification of flood risk sources and confirmation of constraints in the capacity of existing foul and surface water drainage networks and water resources. • Water balance calculations that initially establish the volume of water that is likely to be available on site, and subsequently, determine how the proposed development is likely to change water demand, wastewater generation and surface water runoff. • Identification of a range of water management measures that may be implemented to mitigate the impact of the proposed development, such as demand management systems, Sustainable Drainage Systems, Rainwater Harvesting, Greywater Recycling and Wastewater Recycling. • Multi-Criteria Analysis to evaluate alternative surface water management and water recycling components in order to identify preferred options. • Delivery strategy which defines how the preferred surface water management and water recycling options may be procured, constructed and maintained.
Key recommendations	<ul style="list-style-type: none"> • Surface water should be discharged to the Grand Union Canal, where possible, in order to reduce the risk of sewer flooding and minimise the volume of surface water that is treated at the Beckton Sewage Treatment Works. • Sustainable Drainage Systems should be provided to enable the rainfall generated during events with a return period of up to 1 in 100 years plus 40% climate change that is discharged to existing combined sewers to be restricted to greenfield runoff rates, in order to create capacity within the existing combined sewer network to accommodate additional foul flows generated by the development. • Water meters and water efficient appliances should be provided within all dwellings and commercial units to minimise water demand. Consideration should also be given to the use of Combined Rainwater and Greywater recycling systems to supply appliances that utilise non potable water within commercial tenures. • The existing water supply network should be reinforced to provide capacity to supply the development.
Relations to other studies	Interfaces with the Environmental Standards Study, Utility Study and Infrastructure Delivery Plan
Relevant Local Plan Policies and Chapters	<ul style="list-style-type: none"> • Policy SP2 (Good Growth), SP8 (Green Infrastructure and open space) and SP10 (Integrated Delivery) • All Place policies • Policy EU3 (Water)

Old Oak Common and Park Royal

Integrated Water Management Strategy

**Final Report
April 2017**

Quality information

Document name	Ref	Prepared for	Prepared by	Date	Reviewed by
Updated Final	Final	OPDC	AECOM	April 2017	James Rose

Revision history

Revision	Revision date	Details	Approver Name	Position
1	Nov 2015	First draft	Galo Pinto	Regional Director
2	Jan 2016	Draft2 (consultation)	Galo Pinto	Regional Director
3	Dec 2016	Final	Galo Pinto	Regional Director
4	Apr 2017	IWMS update	Carl Pelling	Associate Director

This document has been prepared by AECOM Limited for the sole use of our client (the "Client") and in accordance with generally accepted consultancy principles, the budget for fees and the terms of reference agreed between AECOM Limited and the Client. Any information provided by third parties and referred to herein has not been checked or verified by AECOM Limited, unless otherwise expressly stated in the document. No third party may rely upon this document without the prior and express written agreement of AECOM Limited.

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 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 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 were 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 were developed as 'strategy options' and these options were defined in order to ensure flexibility of approach to feed into the masterplanning and detailed infrastructure assessment work subsequently undertaken for the Opportunity Area.

Recommendations for how a 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 inform the water policy elements and water management approach included within the Local Plan and has also steered the detailed investigations within the utilities and infrastructure study.

The strategic review of flood risk undertaken for the strategy has also included an assessment of the risk of flooding to the proposed development within Old Oak Common and Park Royal Opportunity Area sufficient to allow completion of the Sequential Test as set out in the national Planning Policy Framework (NPPF). This review therefore supports the Local Plan from an NPPF perspective with respect to flood risk.

Contents

Executive Summary	ii
Contents	1
1 Strategy Background	1
1.1 Introduction	1
1.2 Strategy Aims and Governance	1
1.3 Policy Context	2
2 Site Context and Proposals	5
2.2 Existing Site	6
2.3 Proposed Development.....	8
3 Water Challenges	11
3.1 Drainage and Wastewater.....	11
3.2 Water Resources	11
3.3 Infrastructure Coverage	12
3.4 Flood Risk	14
3.5 Water Challenges Summary	15
4 Opportunity Area Water Cycle	17
4.1 Annual Water Flows	17
4.2 Peak Instantaneous Water Flows	25
5 Water Management Measures.....	28
5.2 Performance Criteria	28
5.3 Demand Management.....	31
5.4 Green Roofs	34
5.5 Roof Water Recycling	36
5.6 Grey Water Recycling	39
5.7 Green Source Control Measures	41
5.8 Below Ground Storage.....	44
5.9 Strategic SuDS Networks.....	46
5.10 Waterway Storage and Discharge	48
5.11 Downstream Stormwater Retention Ponds or Wetlands.....	50
5.12 Stormwater Recycling	52
5.13 Wastewater Recycling.....	54
5.14 Expansion of the Counters Creek Flood Alleviation Scheme.....	58
6 Water Management Options.....	60
6.1 Strategy Formulation	60
6.2 Multi-Criteria Analysis	62
6.3 Stormwater Management Options.....	62
6.4 Recycling Options	67

6.5	Scenario Comparison.....	70
7	IWM Strategy Delivery	76
7.2	Key Delivery Considerations	76
7.3	Potential delivery approaches	78
8	Conclusions and Recommendations	80
8.2	Next Steps for Strategy Development	80

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 Royal Borough of 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;
 - Set a framework which demonstrates workable solutions to the capacity limitations and water challenges facing the development; and

- Provide and assess evidence of flood risk to the Old Oak Common and Park Royal Opportunity Area sufficient to support the statutory requirements of the National Planning Policy Framework (NPPF)

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.

1.2.2 Consultation

1.2.2.1 As part of the Regulation 19 consultation on the draft Local Plan for the Opportunity Area, a draft version of the IWMS was also consulted upon. Responses were received from several parties, and revisions have been made to this final version of the IWMS to address those responses.

1.3 Policy Context

1.3.1.1 The main high level aims and subsequent study objectives (See section 5) have been shaped by several key policy elements of the London Plan and its supporting Supplementary Planning Guidance

1.3.2 The London Plan (March 2015)

1.3.2.1 Development growth within London is driven by the London Plan March 2015¹, which sets out an integrated economic, environmental, transport and social framework for the development of London over a 20-25 year period.

1.3.2.2 The Plan includes a number of key policies aimed to assist protection of the water environment and manage flood risk during redevelopment and construction. In particular, Policy 5.13 (Sustainable Drainage) identifies the drainage hierarchy that all development should follow to manage surface water runoff. Table 1-1 provides a summary of the London Plan policies that are key drivers to the IWMS. The IWMS provides an opportunity to demonstrate how achievable the water based policies are in the context of strategic planning.

Table 1-1: Key London Plan Policy

Policy	Description
Policy 5.3 Sustainable Design and Construction	Development proposals should demonstrate that sustainable design standards are integral to the proposal, including its construction and operation, and ensure that they are considered at the beginning of the design process. Major development proposals should meet the minimum standards outlined in the Mayor's supplementary planning guidance (SPG) and this should be clearly demonstrated within a design and access statement.

Policy	Description
Policy 5.12 Flood Risk Management	<p>Development proposals must comply with the flood risk assessment and management requirements set out in the NPPF and the associated technical Guidance on flood risk over the lifetime of the development and have regard to measures proposed in Thames Estuary 2100 (TE2100) and Catchment Flood Management Plans.</p> <p>Developments which are required to pass the Exceptions Test set out in the NPPF and the Planning Practice Guidance will need to address flood resilient design and emergency planning by demonstrating that:</p> <ul style="list-style-type: none"> • the development will remain safe and operational under flood conditions; • a strategy of either safe evacuation and/or safely remaining in the building is followed under flood conditions; • key services including electricity, water etc. will continue to be provided under flood conditions; • buildings are designed for quick recovery following a flood. <p>Development adjacent to flood defences will be required to protect the integrity of existing flood defences and wherever possible should aim to be set back from the banks of watercourses and those defences to allow their management, maintenance and upgrading to be undertaken in a sustainable and cost effective way.</p>
Policy 5.13 Sustainable Drainage	<p>Development should utilise sustainable urban drainage systems (SuDS) unless there are practical reasons for not doing so, and should aim to achieve greenfield run-off rates and ensure that surface water run-off is managed as close to its source as possible in line with the following drainage hierarchy:</p> <ol style="list-style-type: none"> a) Store rainwater for later use; b) Use infiltration techniques, such as porous surfaces in non-clay areas; c) Attenuate rainwater in ponds or open water features for gradual release; d) Attenuate rainwater by storing in tanks or sealed water features for gradual release; e) Discharge rainwater direct to a watercourse; f) Discharge rainwater to a surface water sewer/drain; g) Discharge rainwater to the combined sewer. <p>Drainage should be designed and implemented in ways that deliver other policy objectives of this Plan, including water use efficiency and quality, biodiversity, amenity and recreation.</p>
Policy 5.14 Water Quality and Wastewater Infrastructure	<p>Development proposals must ensure that adequate wastewater infrastructure capacity is available in tandem with development. Proposals that would benefit water quality, the delivery of the policies in this Plan and of the Thames River Basin Management Plan should be supported while those with adverse impacts should be refused.</p> <p>Development proposals to upgrade London's sewage (including sludge) treatment capacity should be supported provided they utilise best available techniques and energy capture.</p> <p>The development of the Thames Tideway Sewer Tunnels to address London's combined sewer overflows should be supported in principle.</p>
Policy 5.15 Water Use and Supplies Sustainable Drainage	<p>The Mayor will work in partnership with appropriate agencies within London and adjoining regional and local planning authorities to protect and conserve water supplies and resources in order to secure London's needs in a sustainable manner by:</p> <ol style="list-style-type: none"> a) minimising use of mains water; b) reaching cost-effective minimum leakage levels; c) in conjunction with demand side measures, promoting the provision of additional sustainable water resources in a timely and efficient manner, reducing the water supply deficit and achieving security of supply in London; d) minimising the amount of energy consumed in water supply; e) promoting the use of rainwater harvesting and using dual potable and grey water recycling systems, where they are energy and cost-effective; f) maintaining and upgrading water supply infrastructure; g) ensuring the water supplied will not give rise to likely significant adverse effects to the environment particularly designated sites of European importance for nature conservation; <p>Development should minimise the use of mains water by:</p> <ol style="list-style-type: none"> a) incorporating water saving measures and equipment; b) designing residential development so that mains water consumption would meet a target of 105 litres or less per head per day.

1.3.3 Sustainable Design and Construction SPG (April 2014)

The GLA's Sustainable Design and Construction SPG¹ provides guidance on the implementation of London Plan policy 5.3 - Sustainable Design and Construction, as well as a range of policies relating to environmental sustainability. It is a key supporting document for the management of flood risk in London and the implementation of SuDS.

With regards to greenfield runoff rates, the SPG states the following preferred standards:

“ all developments on greenfield sites must maintain greenfield runoff rates. On previously developed sites, runoff rates should not be more than three times the calculated greenfield rate. The only exceptions to this, where greater discharge rates may be acceptable, are where a pumped discharge would be required to meet the standards or where surface water drainage is to tidal waters and therefore would be able to discharge at unrestricted rates provided unacceptable scour would not result”.

However, if it is not practical to achieve greenfield runoff rates, the essential standards for runoff requires a minimum of 50% attenuation of the site's (prior to re-development) surface water runoff at peak times. Developers are required to demonstrate and justify why greenfield runoff rates cannot be achieved, and identify which methods/opportunities have been used to minimise final site runoff, as close to greenfield rate as practical. This should be done using calculations and drawings appropriate to the scale of the application.

¹ Mayor of London, 2014, Sustainable Design and Construction SPG, London Plan 2011 Implementation Framework.

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.

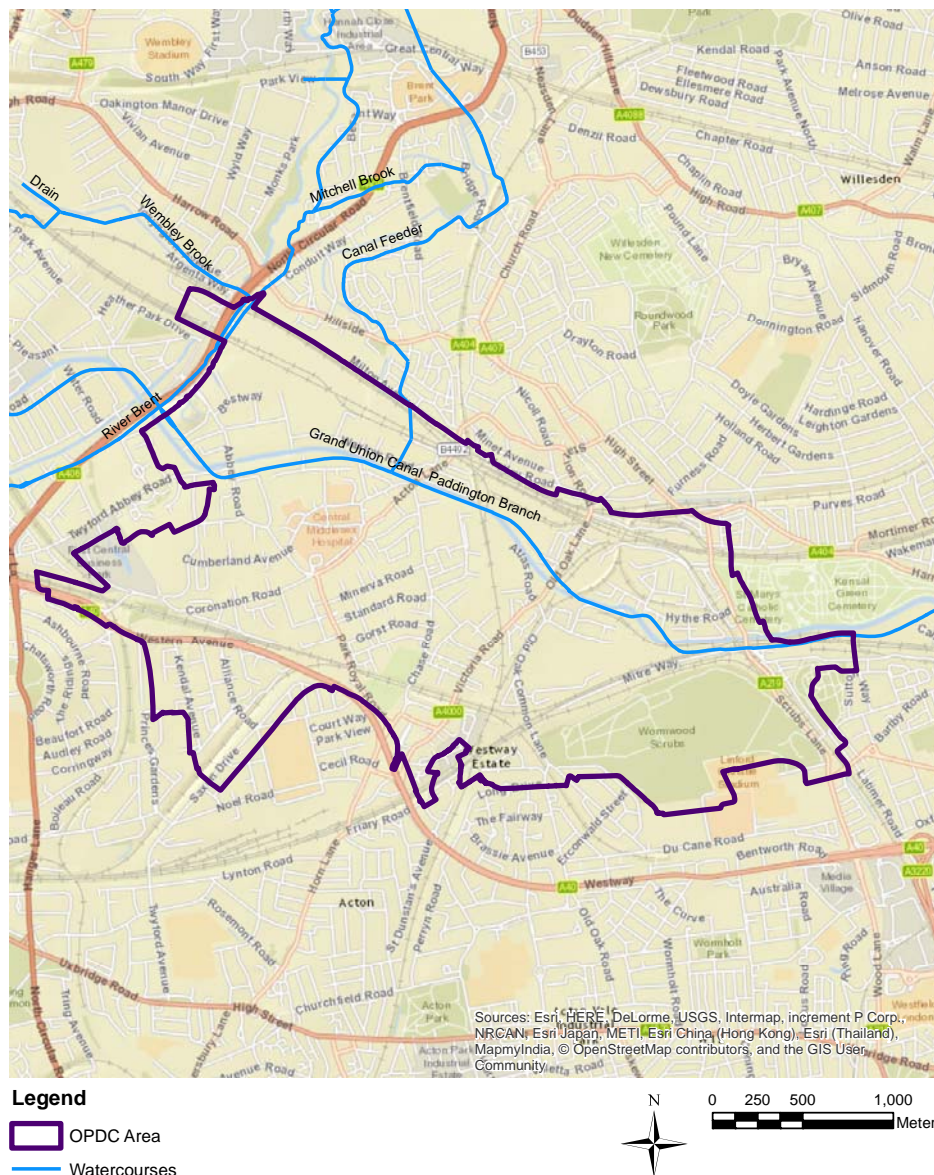


Figure 2-1: Location context of the Old Oak and Park Royal development area

- 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).

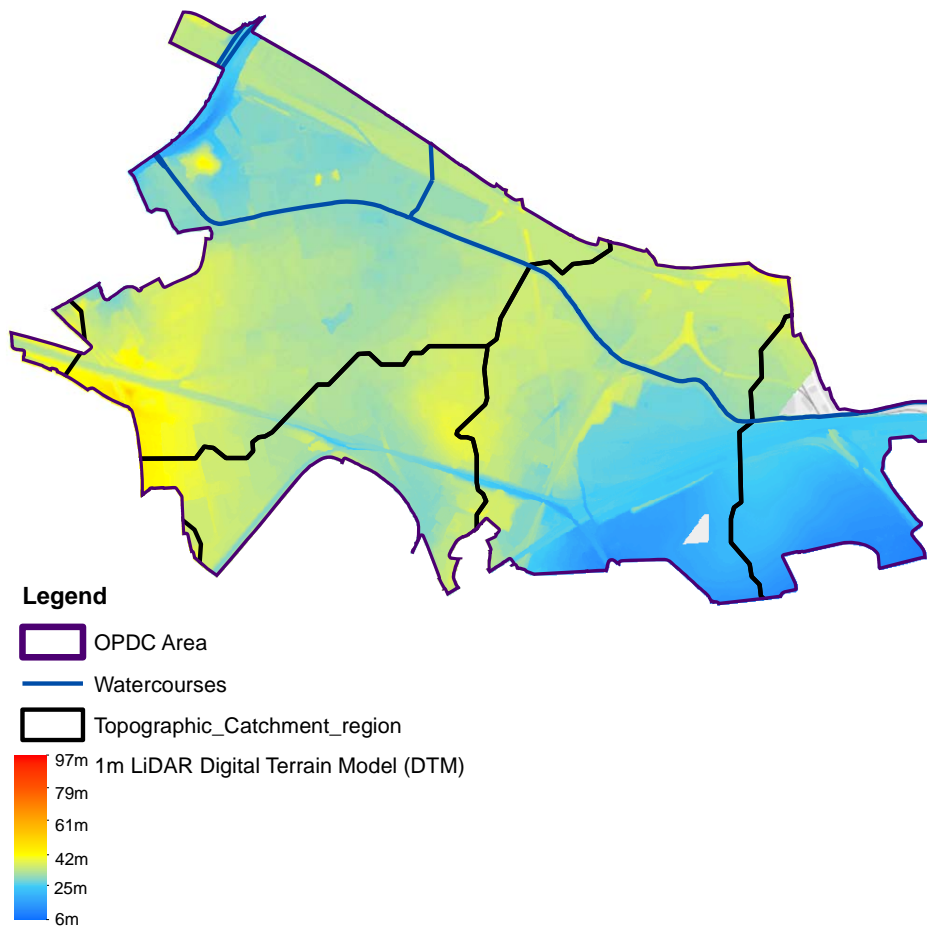


Figure 2-2: Surface topography and natural hydrological catchments across the Opportunity Areas

2.2.2.5 Geology and Groundwater

2.2.2.6 The Opportunity Area lies almost solely on a bedrock of impermeable 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.

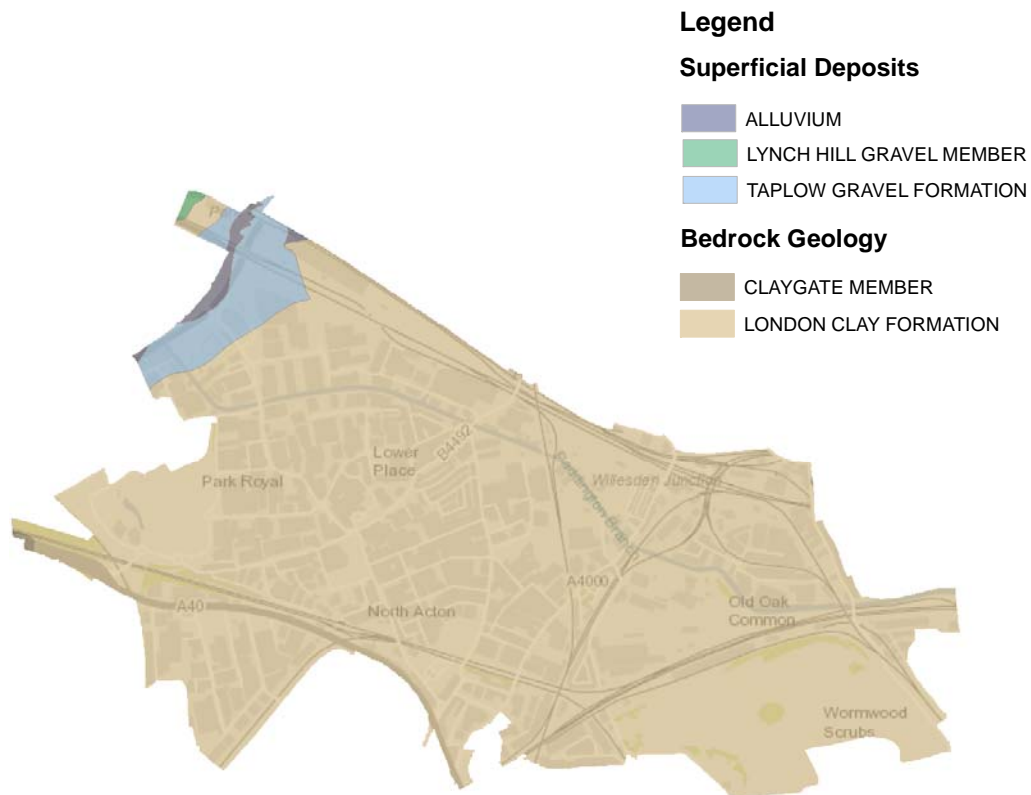


Figure 2-3: Bedrock and superficial geology

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 London²

OAPF	Overview
Wembley	<ul style="list-style-type: none"> • 2,500 new homes • 15,000 jobs • 30,000 m² 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)	<ul style="list-style-type: none"> • 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	<ul style="list-style-type: none"> • 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	<ul style="list-style-type: none"> • 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.

² 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. Whilst there are some parcels of land with separated drainage systems (including the Powerday site which discharges surface water to the Grand Union Canal), nearly 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.
- 3.1.1.5 In terms of direct management of surface water, options for direct infiltration to ground are limited due to the nature of made ground and largely impermeable clay soil and geology underlying most of the site. Whilst some infiltration may be possible depending on site specific analysis, large scale infiltration to manage runoff is unlikely to be feasible within the Opportunity Area.

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-century³ population growth and density will exacerbate these constraints.

³ London 2050 plan

- 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 years⁴, 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.
- 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. 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.

⁴ Thames Water - Resources Management Plan 2015 to 2040 (2015)

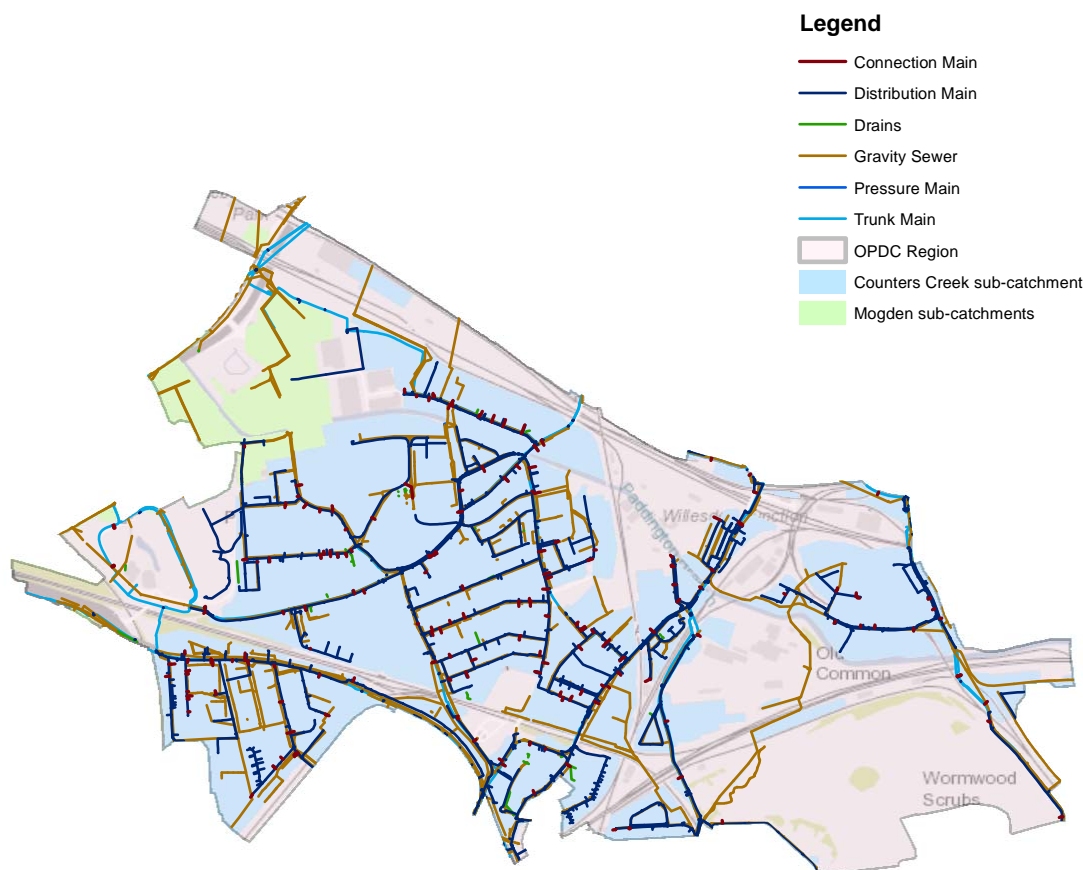


Figure 3-1 – Existing water and wastewater infrastructure

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 will be required and this has been considered within the utilities and infrastructure study which this Strategy document has supported.

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 B. The assessment uses information drawn from the three Borough's Strategic Flood Risk Assessments (SFRAs) as well as other key information and data sources such as the Boroughs Local Flood Risk Management Strategies (LFMRs) relating to all sources of flood risk as set out in the National Planning Policy Framework (NPPF).

3.4.2 Summary of Flood Risk in the Opportunity Area

- 3.4.2.1 Overall, the assessment undertaken for this IWMS (using existing SFRAs) demonstrates that flood risk to the Opportunity Area is relatively low for the majority of flood risk sources.
- 3.4.2.2 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.
- 3.4.2.3 The assessment demonstrates that the main source of flood risk directly affecting the Opportunity Area is surface water flooding using the national Risk of Surface Water flooding dataset⁵. 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.
- 3.4.2.4 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.
- 3.4.2.5 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 B.

⁵ It should be noted that this dataset does not include a climate change event and as such, is not affected by updates to climate change allowance guidance issued in February 2016. However, the new guidance has been used to assess surface water attenuation requirements for climate change related to potential measures (see 4.2.3 and section 5)

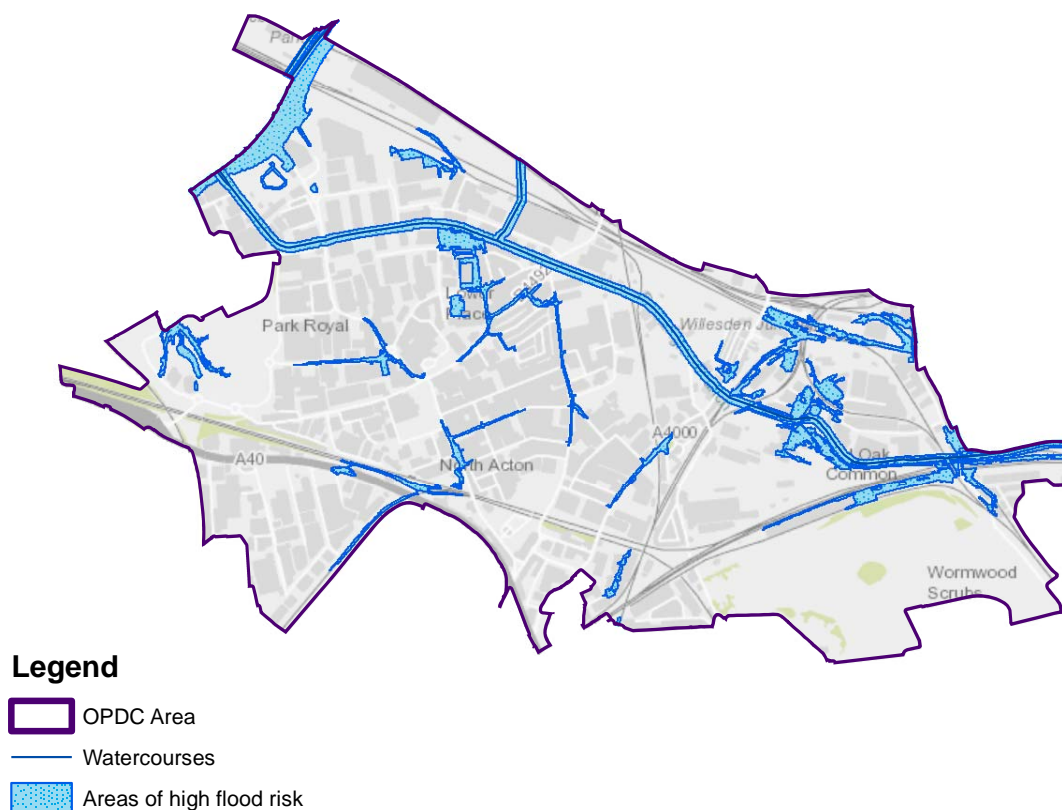


Figure 3-2: Higher flood risk areas within Old Oak and Park Royal

3.4.3 The Sequential Test

- 3.4.3.1 The flood risk information gathered for the purposes of assessing flood risk within this IWMS has used available information from the SFRAs covering the Opportunity Area as well as datasets available from the Environment Agency. This information was sufficient to undertake the NPPF Sequential Test to support the Local Plan, the details of which can be found in Appendix C.
- 3.4.3.2 Because the Opportunity Area is mostly within Flood Zone 1, a Sequential Test was undertaken taking into account all sources of flooding (as advocated by the NPPF and the Planning Practice Guidance), using baseline flood risk information.
- 3.4.3.3 Whilst there are localised areas of higher surface water flood risk across the Opportunity Area, these areas will be significantly influenced by the wholesale redevelopment and changing ground levels across the Opportunity Area. Furthermore, application of the Sequential Test has shown that development of the Opportunity Area passes the Test and that development can be made safe for its lifetime through application of masterplanning and integrated surface water measures outlined within this Strategy document.

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 lack 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
<i>Rainfall</i>	The volume of natural precipitation falling over the Opportunity Areas over an average year.
<i>Roof water</i>	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.
<i>Stormwater</i>	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.
<i>Evapotranspiration</i>	Water which is returned to the atmosphere through the processes of evaporation and transpiration of vegetation, on permeable surfaces.
<i>Infiltration</i>	The proportion of rainwater which infiltrates through the soil, entering the groundwater table.
<i>Potable water</i>	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.
<i>Non-Potable Water</i>	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.
<i>Grey Water</i>	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.
<i>Black Water</i>	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.

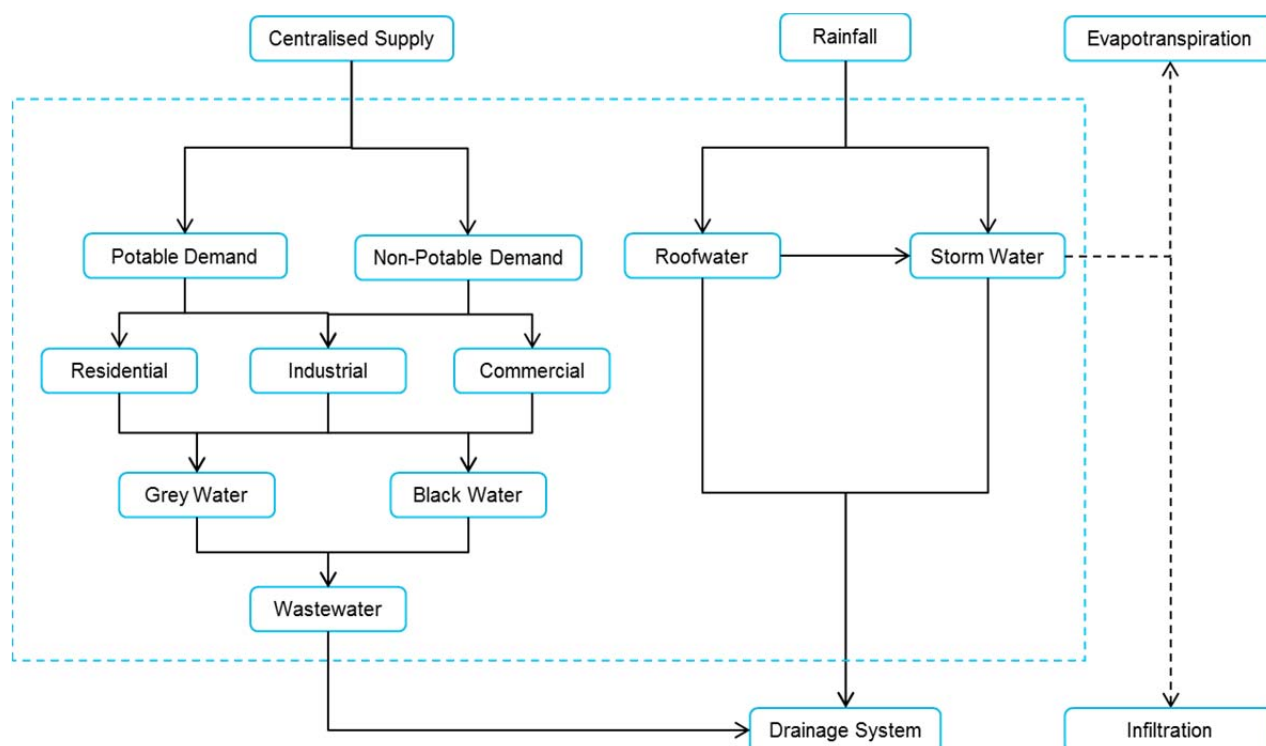


Figure 4-1: Conceptualisation of the pre-development water cycle

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.

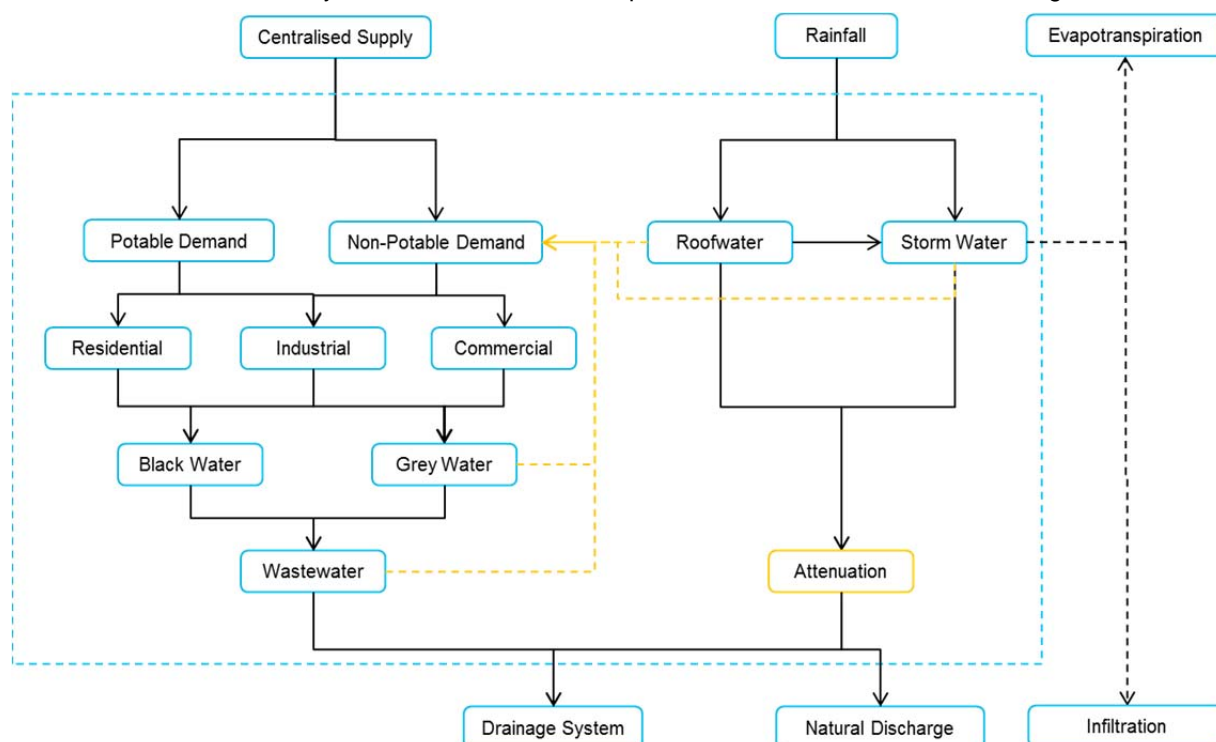


Figure 4-2: Conceptualisation of a post-development water cycle scenario

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 five separate sub-areas, and Old Oak Common was divided into eight 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 C and Figure 4-3 below.

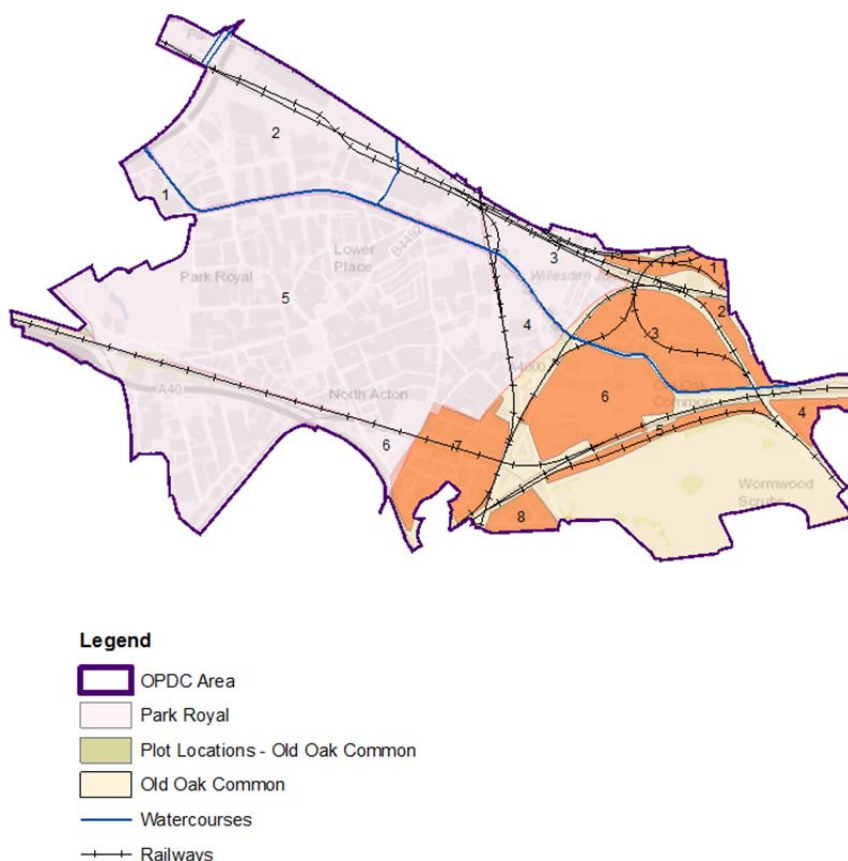


Figure 4-3: Defined sub areas for Old Oak Common (orange) and Park Royal (Purple)

- 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 for the percentage of impervious land cover 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.

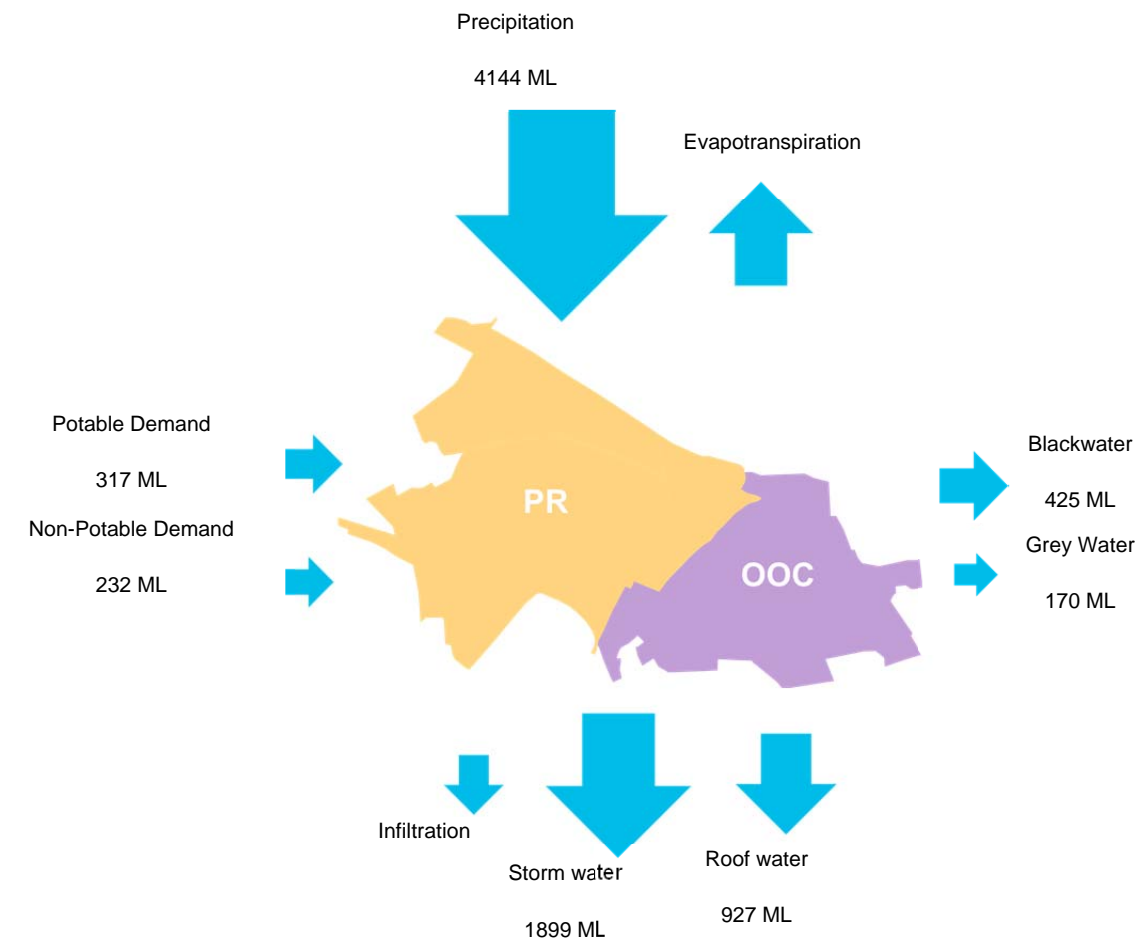


Figure 4-4: Pre-Development annual water balance for the Opportunity Areas

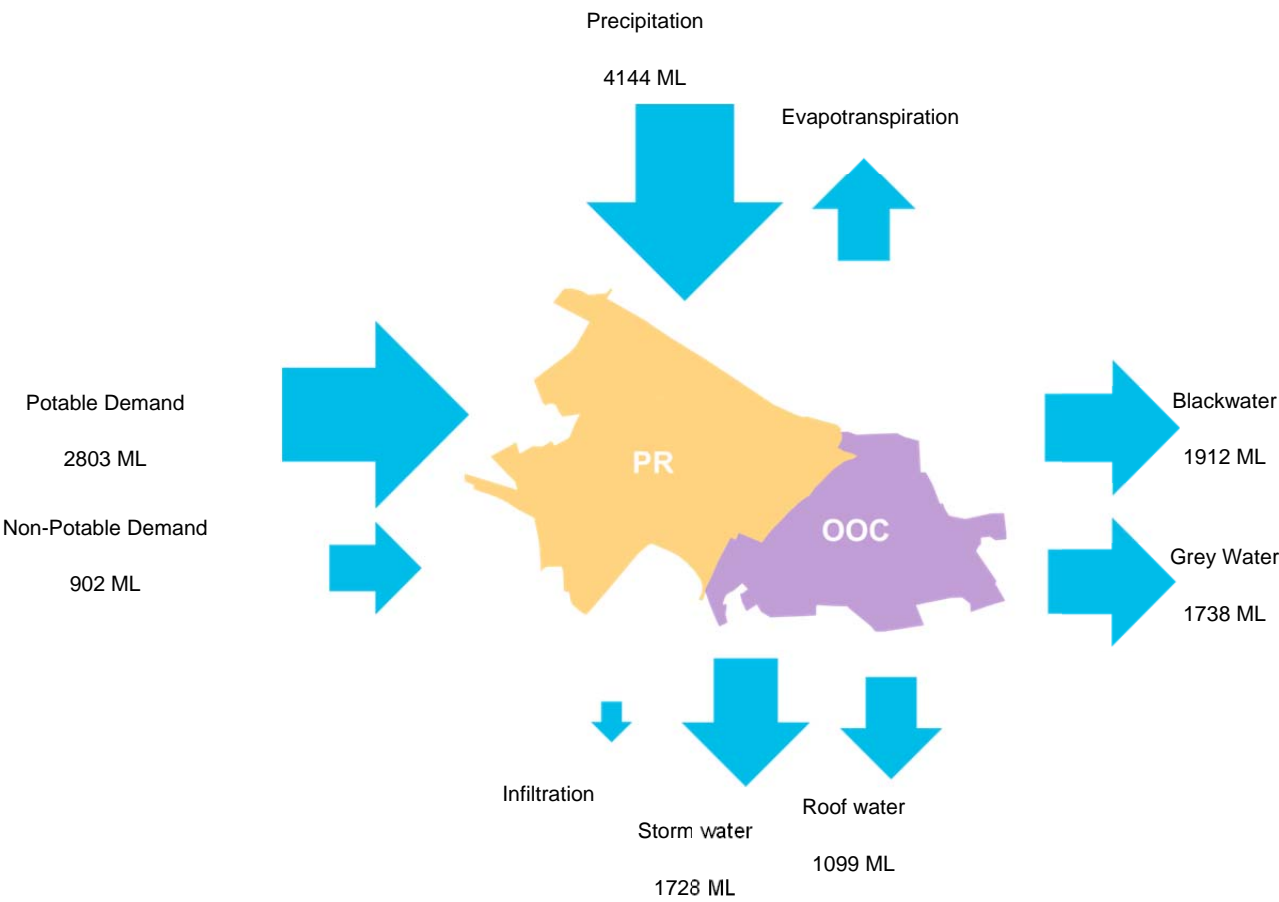


Figure 4-5: Post-Development annual water balance for the Opportunity Areas

- 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.

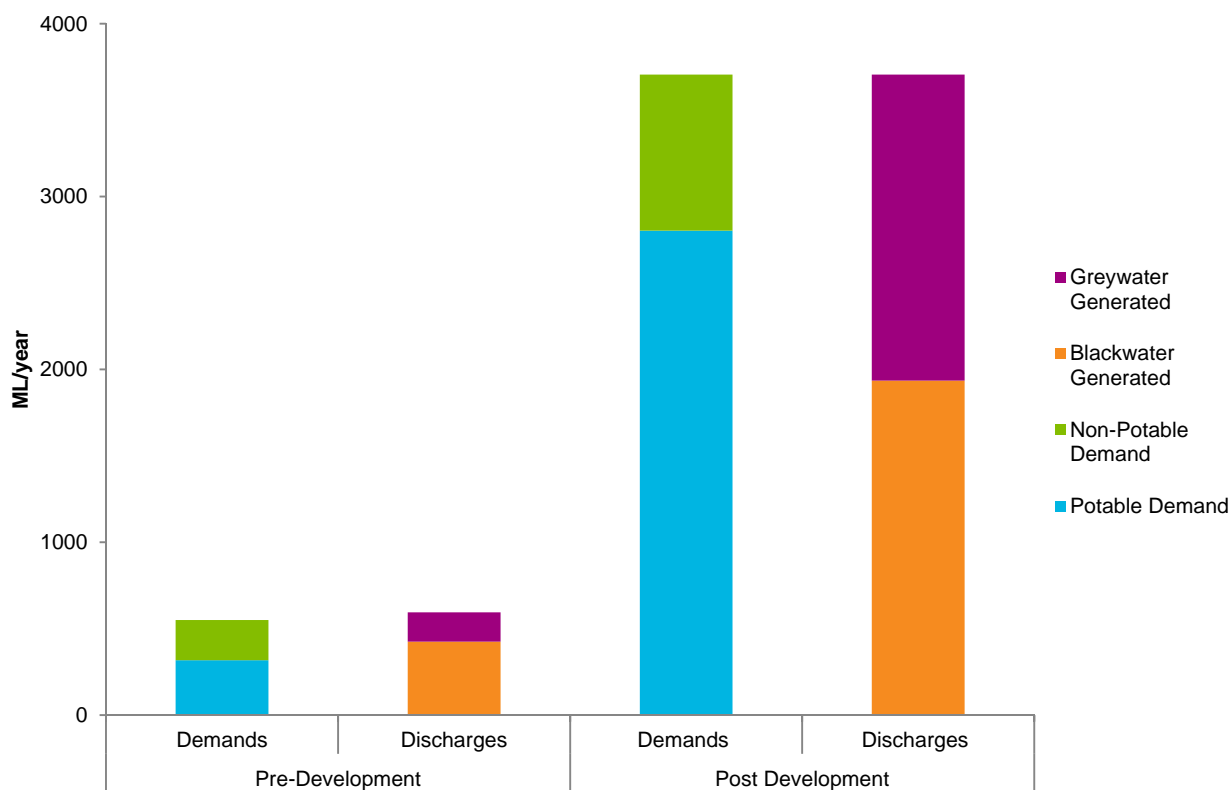


Figure 4-6: Anticipated increase in water requirements over the Opportunity Areas

- 4.1.4.3 As these figures illustrate, without intervention, the proposed development of the Opportunity Areas will increase demand by greater than 600% 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.

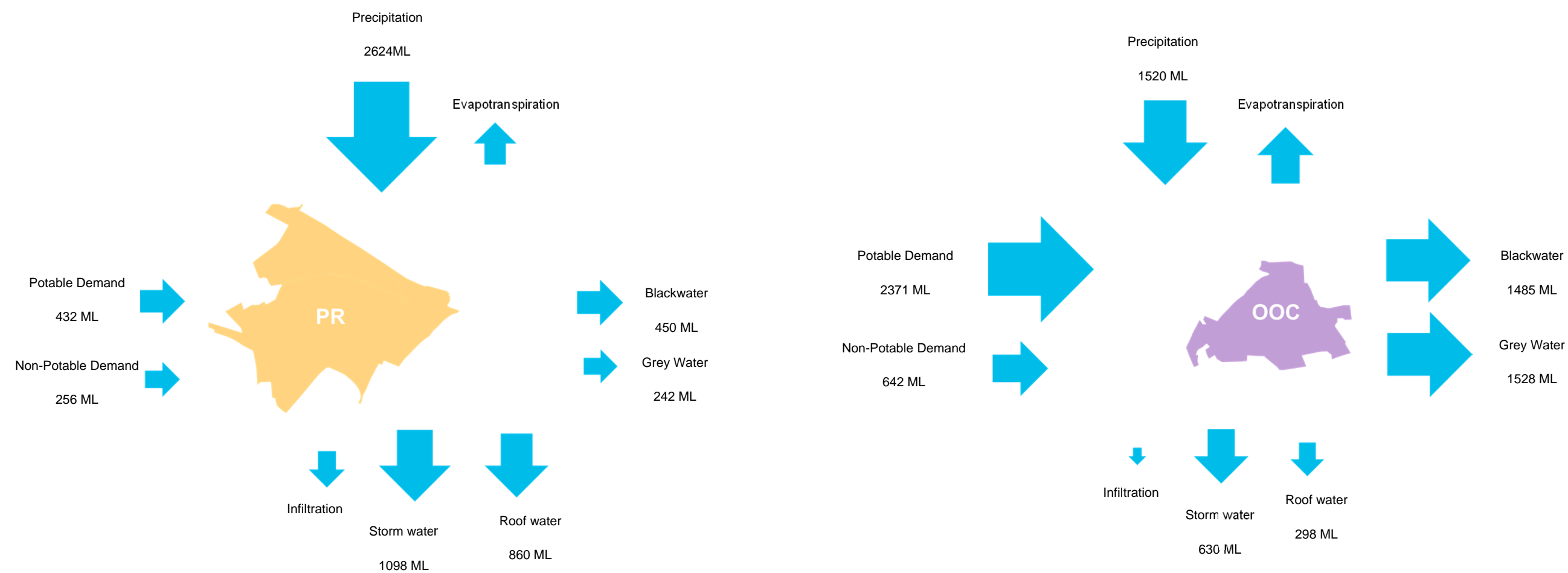


Figure 4-7 - Post-Development annual water balance for the Opportunity Areas

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)⁶. 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.

⁶ Peaking factors based on diurnal profile in *CIRIA 177: Dry Weather Flows in Sewers (1998)*

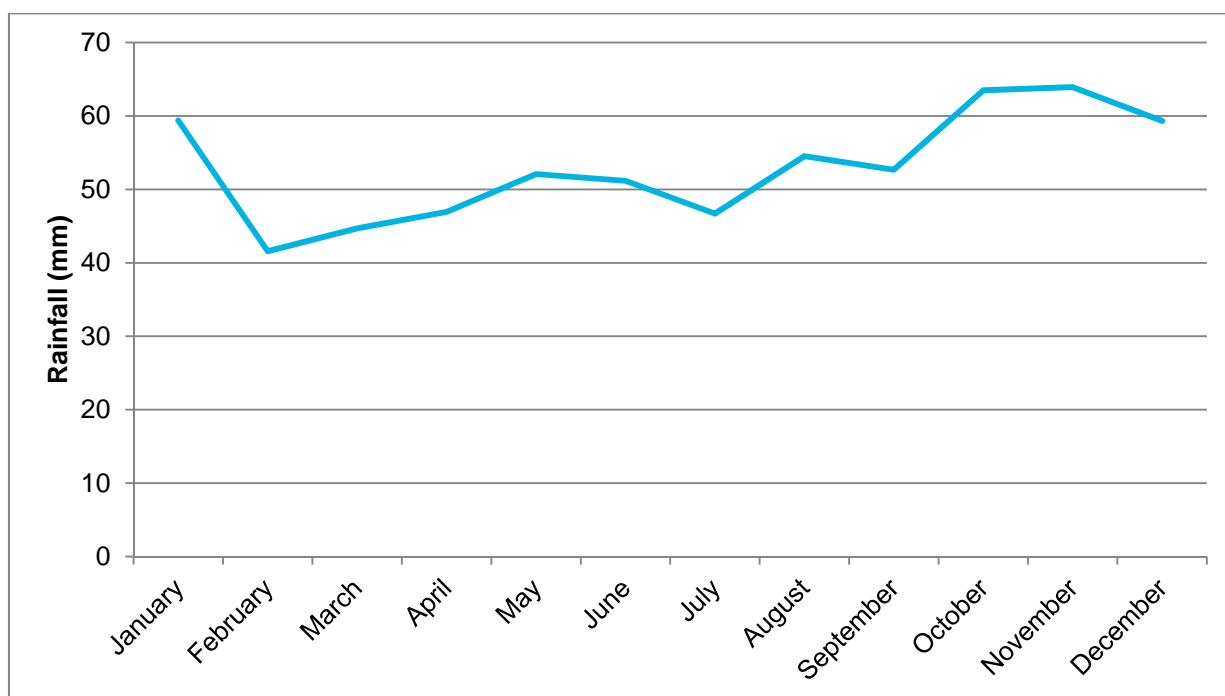


Figure 4-8: London average monthly rainfall (mm), as recorded between 1960 and 2015

- 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 below⁷. 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

⁷ 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 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 plus 40% climate change event have been calculated, and required volumes determined. The volumes required for each drainage 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 (m³)
1	2,133
2	1,709
3	8,695
4	2,025
5	2,892
6	10,581
7	6,759
8	2,038
Total	36,831

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 (m³)
1	4,755
2	62,441
3	17,343
4	7,337
5	124,495
6	44,499
Total	260,871

- 4.2.3.7 It should be noted that these runoff rates and attenuation volumes have been estimated at a high level across a large area. A greenfield runoff rate of 12.5 L/s/ha has been estimated at a central location across the OA; however, this may vary significantly across the extent of the area due to variation in local parameters. It is additionally unlikely that attenuation volumes will be provided in a single volume within each sub-area. As the input parameters are highly dependent on local conditions and drainage system design, it is important that runoff rates and attenuation requirements are confirmed at a site-specific scale during subsequent planning and development stages.

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 to 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 gases 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 radiation, 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.

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 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. There are examples 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.

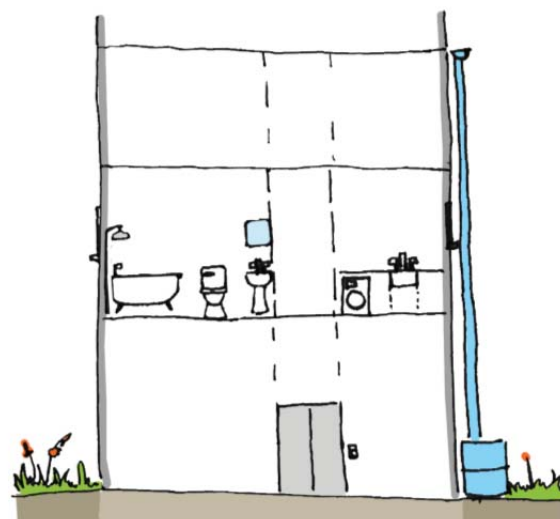


Figure 5-1 - Water efficient fittings

- 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 it 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 are 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.
	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)
	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)
	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)
	Spatial requirements	NONE - Minimal requirements above standard fittings		
	Maintenance Requirements	LOW - Minimal requirements above standard fittings		
	Regulatory and Public Acceptability	HIGH - Supported by current planning policy and regulation. Potential for public acceptability uptake to decrease if user satisfaction diminishes,		
	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.		
	Blue-green space provided	NONE		
	Climate Resilience	MEDIUM - Reduced consumption resulting in reduced strain on existing resources.		
	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 storage 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 buildings, 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.

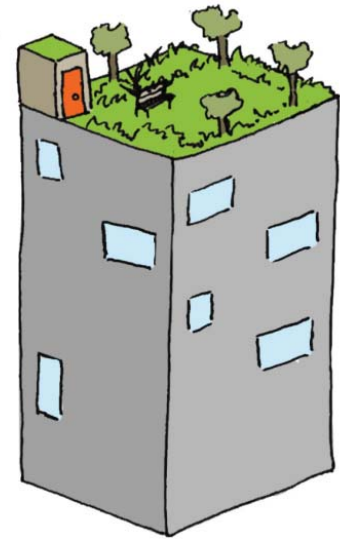


Figure 5-2 - Intensive green roof

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 some limited 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. Choice of plant selection and the substrate composition can impact on 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 5% of required attenuation volume.	HIGH - Estimated water storage capacity of approximately 23% 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 (Commercial tenures only)

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.

5.5.1.2 There is a risk that potable water supplies could become contaminated if non-potable and potable water networks became cross-connected. This risk is higher with residential properties where multiple residents have access to supply networks. It is therefore recommended that roof water recycling is limited to commercial tenures where building systems are typically maintained by facilities management with experience of maintaining complex systems. Commercial tenures are expected to be located on the ground floor of most buildings, which should result in the installation of roof water recycling systems on most new builds.

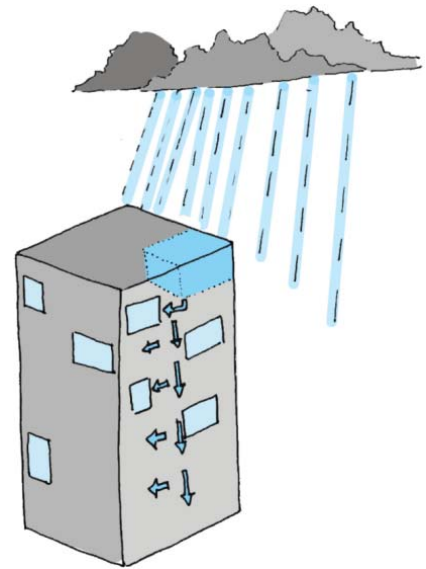


Figure 5-3 - Plot scale roof water harvesting

5.5.1.3 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. 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.

5.5.1.4 It should be noted that combined storage and reuse of 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 could use the same storage mechanism for recycled greywater and storm attenuation, discharging recycled volumes in anticipation of storm events through the use of intelligent control systems.

5.5.1.5 Innovation in Rainwater Harvesting

5.5.1.6 *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 Butler 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.

- 5.5.1.7 *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 with commercial tenures, including collection, filtration, UV disinfection, pumping and non-potable reticulation.
	Applicable Scale	Likely to be most feasible at a building 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 17% reduction in demand (39 ML/year)	LOW - Up to 3% reduction in demand (89 ML/year)
	Potential Discharge Reduction	LOW - Up to 9% reduction of total drainage discharge (197 ML/year)	MEDIUM - Up to 10% reduction of total drainage discharge (39 ML/year)	LOW - Up to 2% reduction of total drainage discharge (89 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.	MEDIUM - 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)	MEDIUM - Estimated 1-2% of capital construction cost (£8,000,000)	LOW - Estimated <1% of capital construction cost (£8,000,000)
	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 (Commercial tenures only)

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.

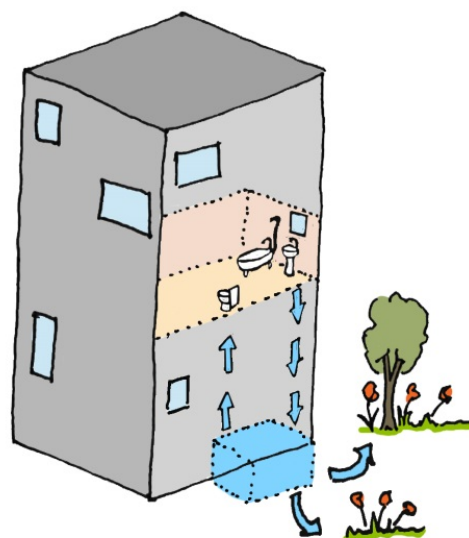


Figure 5-4 - Plot scale grey water reuse

5.6.1.2 There is a risk that potable water supplies could become contaminated if non-potable and potable water networks became cross-connected. This risk is higher with residential properties where multiple residents have access to supply networks. It is therefore recommended that grey water recycling is limited to commercial tenures where building systems are typically maintained by facilities management with experience of maintaining complex systems. Commercial tenures are expected to be located on the ground floor of most buildings, which should result in the installation of grey water recycling systems in most new builds. The location of commercial tenures on the ground floor also means that any pumping will be required to the first floor only, thus limiting energy demands.

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

5.6.1.4 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.

5.6.1.5 Innovation in Grey Water Recycling

5.6.1.6 *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.

		Park Royal - Retained	Park Royal - New Build	Old Oak Common
Characteristics	Assumed Technology	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.	Installation of building scale greywater recycling and non-potable re-use systems for all new buildings.	Installation of building scale grey water recycling and non-potable re-use systems for all new buildings with commercial tenures.
	Applicable Scale		Likely to be most feasible at a building.	
Core Objectives	Potential Potable Water Savings		HIGH - Up to 7% reduction in demand (17 ML/year)	LOW - Up to 4% reduction in total development demand (108 ML/year)
	Potential Discharge Reduction		MEDIUM - Up to 4% reduction of total drainage discharge (17 ML/year)	LOW - Up to 3% reduction of total development drainage discharge (108ML)
	Potential Attenuation Contribution		NONE	
Feasibility	Indicative Cost		LOW - Estimated <1% of capital construction cost (£3, 000,000)	LOW - Estimated <1% of capital construction cost (£5,000,000)
	Spatial requirements		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.	
	Maintenance Requirements		HIGH - Inspection and cleaning of collection and treatment systems including filters valves and pumps.	
	Regulatory and Public Acceptability		HIGH - Potential for some public perception issues and regulatory barriers, depending on proposed end uses.	
	Flexibility and scalability		HIGH - Highly scalable system with minimal space requirements.	
Sustainability	Carbon intensity	HIGH - Ongoing energy and maintenance requirements. Potential for lost efficiencies through delivery of numerous localised solutions.		
	Blue-green space provided	NONE		
	Climate Resilience	HIGH - Highly consistent supply of water with low climate dependency, resulting in minimal storage requirements.		
	Surface water quality	LOW - Marginal benefit through reduced flows to sewer, with reduced associated impact on downstream receiving waterbodies.		

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.

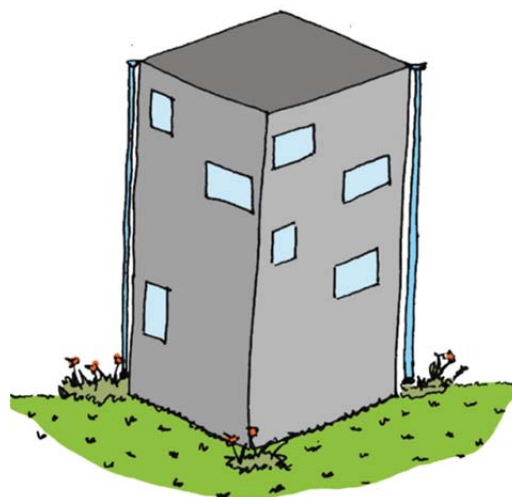


Figure 5-5 - Plot scale raingardens

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 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)⁸ 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 ‘water sensitive urban design’ (WSUD). CIRIA’s UK WSUD Scoping Study (2013) and associated ideas book highlights how this approach

⁸ SuDS Manual, CIRIA (2015) - <http://www.susdrain.org/resources/ciria-guidance.html>

applies to different urban character areas⁹. 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 as 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)

⁹ 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 3% 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.

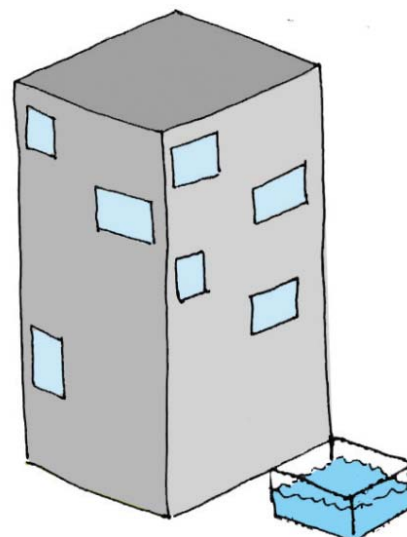


Figure 5-7 - Underground stormwater attenuation

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.
	Applicable Scale	Plot or development scale is likely to be most suitable.		
Core Objectives	Potential Potable Water Savings	NONE		
	Potential Discharge Reduction	NONE		
	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 (£114,000,000)	MEDIUM - Estimated 1-2% of capital construction cost (£9,000,000)	LOW - Estimated 0-1% of capital construction cost (£13,000,000)
	Spatial requirements	LOW - Significant volumes are required to meet greenfield runoff rates. However, underground installation minimises effective land requirements.		
	Maintenance Requirements	MEDIUM - Regular inspection of silt traps, manholes, pipework and pre-treatment devices, with removal of sediment and debris as required.		
	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. 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.		
	Blue-green space provided	NONE		
	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.		
	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.

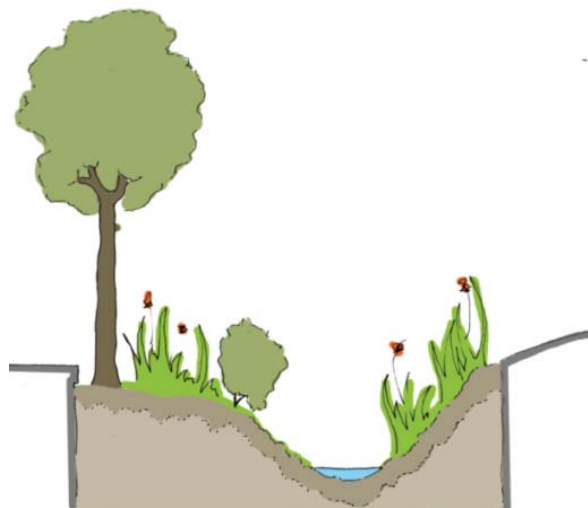


Figure 5-8 - Streetscape swales

- 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 12% of attenuation required, dependant on spatial availability.	HIGH - Estimated 39% 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 Grand Union Canal Storage and Discharge

5.10.1.1 The development areas are located adjacent to a 43km long pound of the Grand Union Canal. To avoid overloading or exacerbating the sewer flooding issues within the Counters Creek catchment, it is possible to discharge surface water within parts of Old Oak Common, and certain areas of Park Royal (including the New Build areas) to the Grand Union Canal. 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 5-9 - Stormwater discharge to local waterways

5.10.1.2 It is likely that upgrades to the Grand Union Canal would be needed to ensure it can accommodate any additional discharge. The requirements of any upgrade would be informed by detailed drainage designs of the proposed development and hydraulic modelling of the canal system. These measures would ensure that there was no increase in flood risk to the canal system as a result of the additional discharge.

5.10.1.3 Appropriate water quality management measures would be required to ensure no adverse impacts on the watercourse quality. The Canal and River Trust have indicated that the following would be required:

- Installation of a Class 1 oil interceptor prior to each discharge point into the waterway.
- Adherence to the Environment Agency's PPG3 guidance note on oil separators. This includes ensuring separators are appropriately sized and silt storage accommodated.
- Sufficient access points included in the design to allow for inspection and cleaning of the internal chambers.
- Applicant would need to submit a maintenance procedure for the oil separator(s) that encompasses the maintenance requirements of PPG3.
- Measures to be provided to prevent pathways between the canal and potential sources of existing ground contamination. It is suggested that any surface water drainage systems and Sustainable Drainage Systems be lined.

Detailed consultation with the Environment Agency, the Canal and The River Trust would be required in further scoping these options.

5.10.1.4 As an alternative to the canal being the final point of discharge, it may be possible to use the Grand Union Canal for temporary storage and conveyance of peak surface water flows, which could be subsequently extracted to avoid any net increase in flows. This option is being considered further in the infrastructure study.

		Park Royal - Retained	Park Royal - New Build	Old Oak Common
Characteristics	Assumed Technology	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.	Managed discharge or storage of runoff to the Grand Union Canal, through connection of new sustainable drainage infrastructure.
	Applicable Scale	Development or area wide scale		
Core Objectives	Potential Potable Water Savings	NONE		
	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)
	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	LOW – Estimated <1% of capital construction costs (£6,000,000) Without the detailed modelling by the Canal and River Trust, it is not possible to confirm costs associated with the upgrade of the Grand Union Canal to accommodate the additional discharge, so an estimate has been made at this stage. Provision of a new surface water drainage network to convey drainage to the Grand Union Canal would also be required (as discussed above).		
	Spatial requirements	LOW - Minimal, excepting associated spatial requirements for surface drainage and attenuation systems (discussed separately)		
	Maintenance Requirements	Primary requirements will be as associated with related drainage and attenuation infrastructure. Potential for additional ongoing costs related to discharge.		
	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.		
	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.		
	Blue-green space provided	NONE - no direct impact; however, this may be provided through delivery of associated drainage infrastructure.		
	Climate Resilience	MEDIUM - removing surface water flows from the sewer system will assist in mitigating the impacts of climate change on drainage.		

	Park Royal - Retained	Park Royal - New Build	Old Oak Common
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.

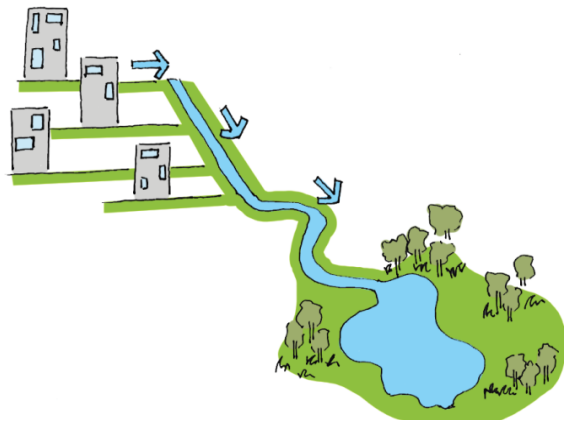


Figure 5-10 - Downstream stormwater attenuation

- 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 (£137,000,000)	LOW - Estimated 0-1% of estimated construction costs (£30,000,000)	
	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

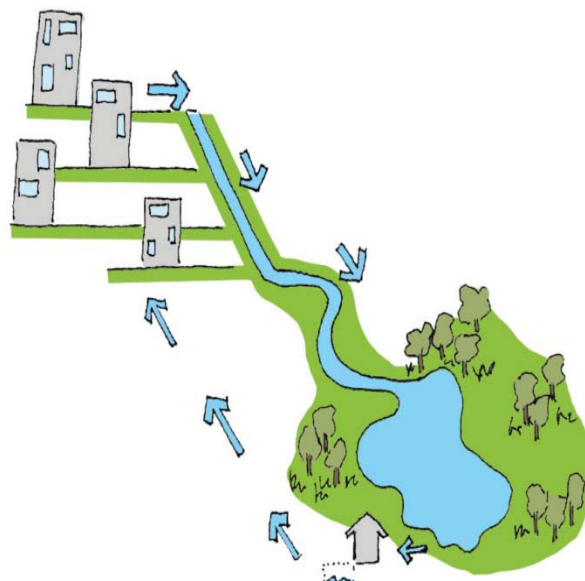


Figure 5-11 - Stormwater harvesting and reuse

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.

- 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.	
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.			
Indicative Cost	MEDIUM - Estimated 1-2% of anticipated construction costs (£50,000,000)			
Feasibility	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).

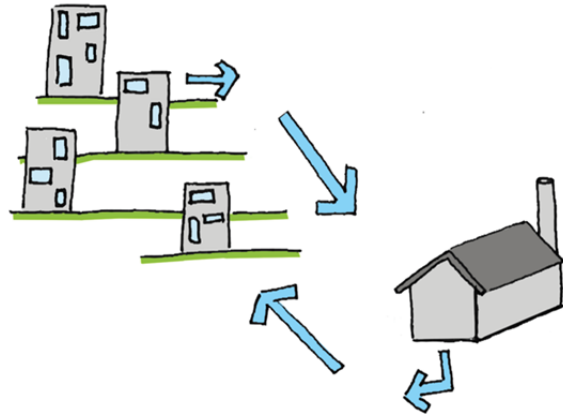


Figure 5-12 - Wastewater recycling

- 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 1,400m³ – 2,900m³ 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 are currently working with Welsh Water, Affinity Water, Wessex Water, United Utilities and Northumberland Water to trial 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® 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 biomedica into the reaction tanks. The root system of the planting and the biomedica 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 biomedica creates a biofilm with a much greater surface area, allowing oxygen to be absorbed more efficiently. Because the root structure and biomedica 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 (see figure 5-14 below) with an 80,000m³/day FRC unlocked a large area of development land previously taken up by the former plant and buffer area.



Figure 5-14 - Organica's 80,000m³ plant in South Pest (source: Organicawater.com)

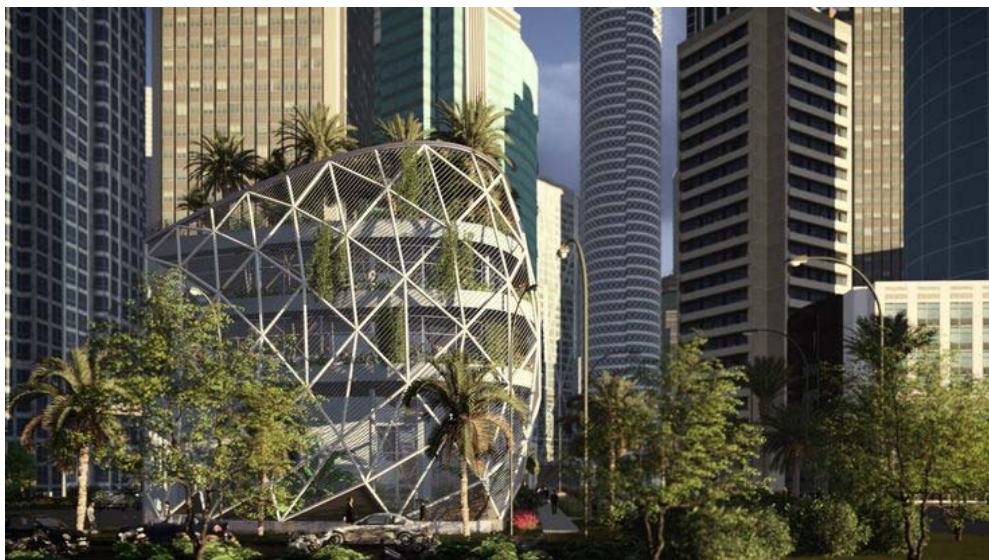


Figure 5-15 - 2,000m³ waste water treatment plant, Jakarta (source: Organicawater.com)

		Park Royal - Retained	Park Royal - New Build	Old Oak Common
Characteristics	Assumed Technology	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.	Package wastewater treatment plant to treat incoming sewage, incorporating advanced water treatment, and redistribution for non-potable reuse within homes and businesses.	
	Applicable Scale		Area scale. Building or development scale wastewater recycling systems are also possible; however, greywater recycling is likely to be more appropriate in this instance.	
Potential Potable Water Savings	HIGH - Up to 21% reduction in potable demand (681ML/year)			
Potential Discharge Reduction	MEDIUM - Up to 17% reduction in total drainage discharge (681ML/year)			
Potential Attenuation Contribution	NONE			
Indicative Cost	LOW - Estimated 0-1% of anticipated construction costs (£44,000,000)			
Feasibility	Spatial requirements	MEDIUM - Spatial requirements associated with infrastructure for wastewater collection, treatment, storage and distribution.		
	Maintenance Requirements	HIGH - 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. Potential community concerns associated with potential for noise and odour (these can be mitigated)		
	Flexibility and scalability	MEDIUM - May be more difficult to phase delivery in line with development; however, new technologies have the potential for innovative designs with modular composition.		
	Carbon intensity	HIGH - Ongoing energy and maintenance requirements.		
Sustainability	Blue-green space provided	MEDIUM - Minimal provided through traditional design. However, new technologies may provide opportunities for use of green, biological treatment processes.		
	Climate Resilience	HIGH - Highly reliable supply with limited climate dependence.		
	Surface water quality	LOW - Marginal benefit through reduced flows to sewer, with reduced associated impact on downstream receiving waterbodies.		

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 (DWF) into the public sewer system. The use and operation of all combined sewer overflows as well as the Thames Tideway Tunnel are regulated by the Environment Agency via permits. These permits state the maximum dry weather flow permitted by such infrastructure and any increase in discharge above the stated levels would be a breach of these discharge permits. Development at Old Oak Common cannot be accommodated by the new Counters Creek storm relief sewer as it has the potential to increase the dry weather flow directly into the environment either via combined sewer overflow or the Thames Tideway Tunnel.

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 reduce the returning capacity in the local and interceptor sewers by removing surface water, using a combination of techniques outlined in this report.

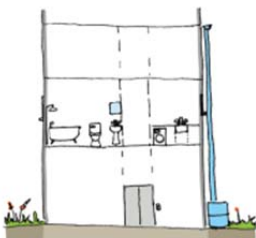

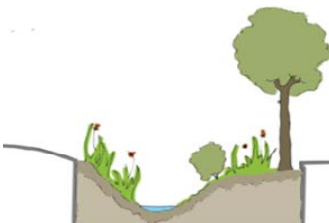

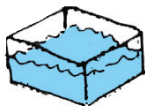

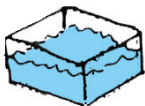

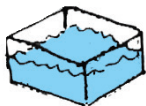

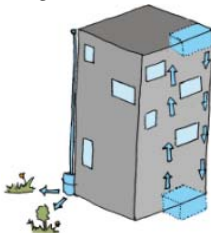
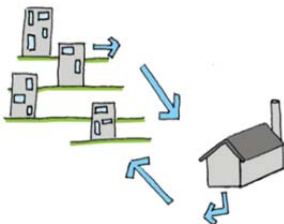

		Park Royal - Retained	Park Royal - New Build	Old Oak Common
Characteristics	Assumed Technology	Expansion of the Counters Creek Flood Alleviation Scheme to provide additional conventional drainage capacity across the Opportunity Areas.		
	Applicable Scale	Regional scale solution		
Core Objectives	Potential 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 need 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 be 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 managing 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

Strategy Components	Demand Management		Maximising demand management through water efficiency, community engagement and utilisation of smart network technologies.								
	Stormwater Management Options		Green source control features to manage the quality and quantity of surface water generated on site								
			Streetscape strategic SuDS network providing conveyance, filtration and attenuation of stormwater from development plots to attenuation or discharge locations.								
			Discharge of attenuated stormwater into the Grand Union Canal to reduce discharge to the existing sewer network.								
			Residual attenuation provided underground	Residual attenuation provided above ground	Residual attenuation provided underground	Residual attenuation provided above ground	Residual attenuation provided underground	Residual attenuation provided above ground			
											
Water Recycling Options		Building scale greywater recycling		Strategic scale wastewater recycling		Strategic scale storm water recycling					
											
Scenario 1		Scenario 2		Scenario 3		Scenario 4		Scenario 5		Scenario 6	

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 and Discharge 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, the Grand Union Canal 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 manage stormwater across the development.
- 6.3.2.2 The MCA preferred surface management option is to discharge stormwater in to the Grand Union Canal. Discharge rates to the Grand Union Canal should be targeted to reflect greenfield runoff, and therefore this option would need to be considered in conjunction with above and underground stormwater attenuation measures.
- 6.3.2.3 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. In addition, to the Grand Union Canal, there are several other (less-preferred) options available for discharge of the collected, attenuated, treated and conveyed stormwater, including:
- Discharge to the combined Counters Creek sewer system;
 - Discharge to the Mogden surface water catchment;
 - Harvesting and reuse for recycling.
- 6.3.2.4 The preferences for providing attenuation storage are described below:
- 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, assuming a universal application across these sites, these have the potential to provide up to approximately 20%¹⁰ 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 approximately 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.
- 6.3.2.5 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).

¹⁰ It should be noted that this does not equate to a 20% reduction

- 6.3.2.6 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.
- 6.3.2.7 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.
- 6.3.2.8 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.
- 6.3.2.9 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.

6.3.3 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 particular, 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 be 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 provided there is appropriate management of water quality and quantity for this to be achieved without exacerbating flood risk or impacting on the quality of waterways.

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		Grand Union Canal Discharge	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		1	5	3	2	6	4

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		Grand Union Canal Discharge	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		1	5	3	2	6	4

KEY

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

6.4 Recycling Options

- 6.4.1.1 The installation of a non-potable water recycling solution for the development areas is an important consideration 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 reduce potable water demand with greater savings possible through outdoor use of water for public irrigation or specific commercial and industrial process demands.
- 6.4.1.2 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 augment centralised water supplies. These are described below, with reference to the outcomes of the MCA:

1) *Greywater and Roof water Recycling (Scenarios 1 and 2)*

Greywater recycling for plot-based commercial tenures is indicated to be the preferred option for delivering non-potable reuse within the development. It offers greater climate resilience and associated certainty of supply, flexibility in scale and phasing of delivery and less spatial challenges. In addition, operational and maintenance is considered to be simplified by retaining responsibilities within a given building facilities management.

Roof water recycling has been assessed as the second preference for a non-potable reuse option across the development. Due to the plot-based, scalable nature of these solutions, along with the cost and infrastructure efficiencies, it is recommended that greywater and roof water recycling are considered in combination. It is likely that the preferred solution may vary for individual developments, depending on the rooftop and demand characteristics, and the presence of commercial tenures.

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

Developing a strategic wastewater recycling network would present challenges in ownership, delivery and operation, potentially requiring cooperation between numerous developers and a large strategic network to be operated and maintained by a third party. There are advantages of this system when compared to stormwater recycling; wastewater recycling has a higher climate resilience and associated certainty of supply. This option 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. However, plot-scale options provide more flexibility and ease of implementation and management.

Importantly, the effectiveness of this option is underpinned by the collection and reuse of both domestic and commercial reuse. As previously outlined for greywater and roof water recycling there is a risk that potable water supplies could become contaminated if non-potable and potable water networks became cross-connected. This risk is higher with residential properties where multiple residents have access to supply networks. Therefore, this option would only be suitable for commercial tenures which will make it considerably less cost-effective.

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

Stormwater recycling is indicated to be an alternative approach to providing a network-based non-potable supply solution. Again, this strategic option would present challenges in ownership, delivery and operation, potentially requiring cooperation between numerous developers and a large strategic network to be operated and maintained by a third party.

Climate dependence is a further 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. More detailed assessment and modelling would be 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.

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.

- 6.4.2.2 Whilst a preferred option has been suggested, it is likely that a range of approaches will need to be adopted. 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. In the long term, the overall objective should be to provide a diverse portfolio of fit-for-purpose 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 (commercial tenures only)	Roof water recycling for non-potable reuse (commercial tenures only)
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		3	4	1	2

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 (greywater, wastewater or stormwater) 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 Some of 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. Greywater recycling is, 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.
 - Ultimate discharge of stormwater into the Grand Union Canal, thus reducing discharges into the existing sewer network;
- 6.5.1.4 A conceptual diagram of the proposed preferred strategy is also presented in Figure 6-2 for illustrative purposes (it should be noted that the spatial configuration indicated has not been confirmed in this figure).

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, non-potable demand for new commercial development is met through greywater and roof water recycling units provided at site level.	<ul style="list-style-type: none"> ✓ No strategic scale infrastructure required – ease of deliverability and phasing. ✓ Climate resilient supply of recycled water for commercial tenure non-potable demand. ✓ Future flexibility for use of storm water for other non-potable or potable demands. 	<ul style="list-style-type: none"> × Minimal provision of multi-beneficial open spaces. 	This scenario focuses on ease of deliverability but 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, non-potable demand for new commercial development is met through greywater and roof water recycling units provided at site level.	<ul style="list-style-type: none"> ✓ Creates opportunity for multi-functional open space through provision of surface water SuDS. ✓ Climate resilient supply of recycled water for commercial tenure 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. 	<ul style="list-style-type: none"> × Significant amount of open space required to deliver preferred storm water management. × More challenging delivery of strategic storm water management which could affect phasing. 	This scenario balances deliverability against cost efficiency, and also provide multi-beneficial above ground water storage measures.

Scenario	Scenario Description	Advantages	Disadvantages	Summary
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, non-potable demand for new commercial development is met through recycling of wastewater and roof water from development at a central treatment unit and provided to buildings through a dedicated area-wide pipe distribution network.	<ul style="list-style-type: none"> ✓ More straightforward delivery of on-site storm water management option ✓ Climate resilient supply of re-cycled water for commercial tenure non-potable demand. ✓ Future flexibility for use of storm water for other non-potable or potable demands. 	<ul style="list-style-type: none"> × 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. × Less efficient to deliver and maintain strategic option for commercial tenures only. 	This scenario balances deliverability against cost efficiency, but provides less opportunity for the creation of multi-beneficial space.
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, non-potable demand for new commercial development is met through greywater and roof water recycling units provided at site level.	<ul style="list-style-type: none"> ✓ Creates opportunity for multi-functional open space through provision of surface water SuDS. ✓ Climate resilient supply of re-cycled water for non-potable demand. 	<ul style="list-style-type: none"> × 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. × Less efficient to deliver and maintain strategic option for commercial tenures only. 	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, non-potable demand for new commercial development is met through recycling of wastewater from development at a central treatment unit and provided to	<ul style="list-style-type: none"> ✓ More straightforward delivery of on-site storm water management option ✓ Creates opportunity for multi-functional open space through provision of surface water SuDS. 	<ul style="list-style-type: none"> × Minimal provision of multi-beneficial open spaces. × More challenging delivery of strategic re-use option which could affect phasing. 	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

Scenario	Scenario Description	Advantages	Disadvantages	Summary
	buildings through a dedicated area-wide pipe distribution network.		<ul style="list-style-type: none"> × Less climate resilient water re-use option. × Less efficient to deliver and maintain strategic option for commercial tenures only. 	
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, non-potable demand for new commercial 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.	<ul style="list-style-type: none"> ✓ Creates opportunity for multi-functional open space through provision of surface water SuDS. 	<ul style="list-style-type: none"> × More challenging delivery of strategic storm water management and re-use option which could affect phasing. × Less climate resilient water re-use option. × Less efficient to deliver and maintain strategic option for commercial tenures only. 	This is a challenging scenario to deliver in terms of phasing and offers less resilience to drought conditions and dry periods.

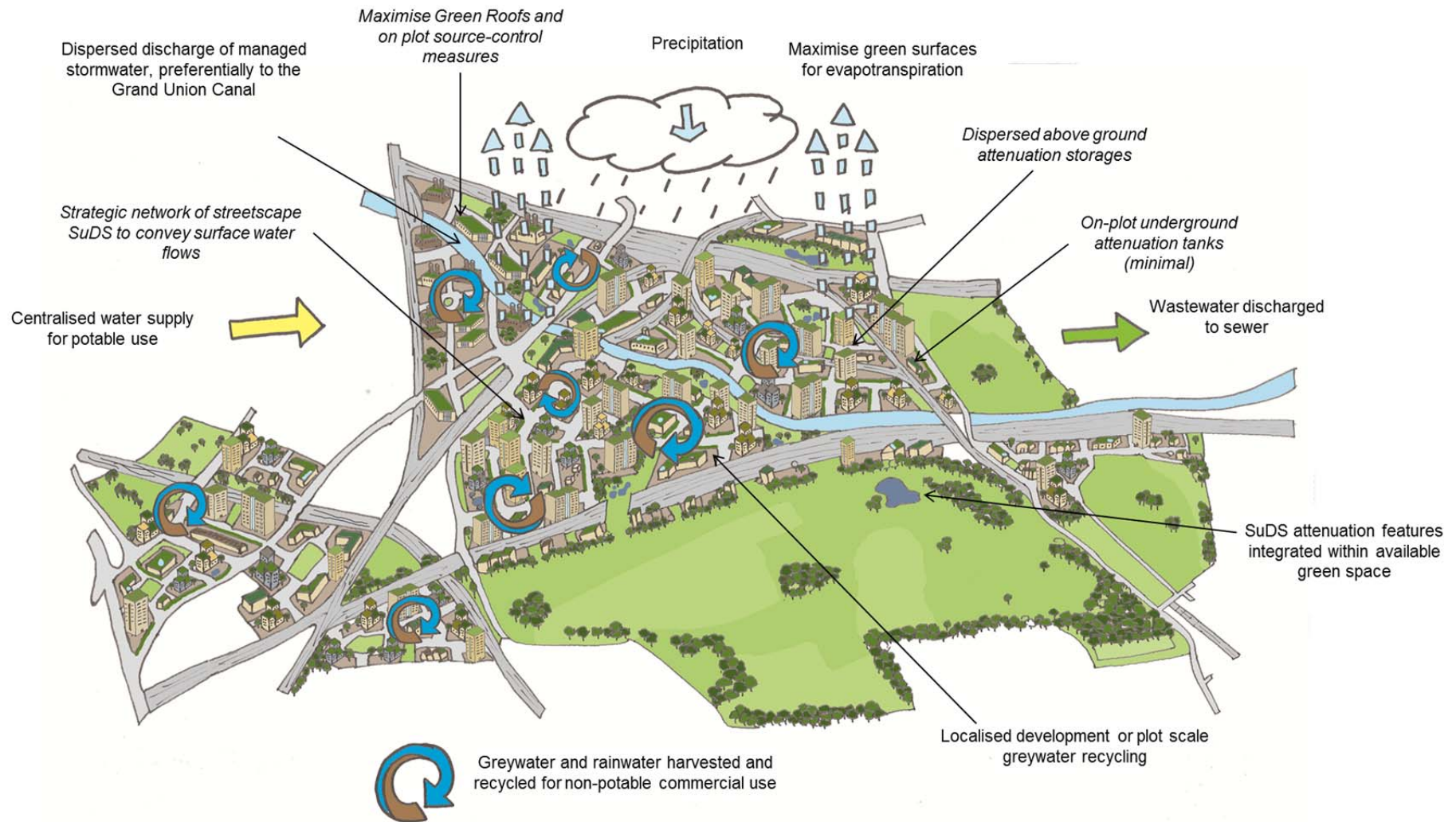


Figure 6-2: illustrates Scenario 2, which has been selected as the preferred approach to integrated water management across the development areas. Storm water runoff is treated and managed via attenuation, which is preferentially provided through on-plot and above-ground blue-green infrastructure, in line with the hierarchy specified in Section 6.2.1, and preferentially discharged to the Grand Union Canal. To reduce overall demand, water efficiency is maximised and commercial tenure non-potable demand is met through greywater and roof water recycling units, provided at a plot scale.

6.6 Strategy Overview

6.6.1.1 The identification of six potential option strategies provides a degree of flexibility for the overall Strategy prior to developing a preferred solution in detail as masterplanning develops. However, in order to provide input to the next stage of planning the key elements of an example scenario (in this case, scenario 2) has been described in more detail in Table 6-7: below, including the different approaches required between redevelopment areas within Old Oak and Park Royal and existing areas of Park Royal.:

Table 6-7: Summary of example option scenario 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	<ul style="list-style-type: none"> 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. 	<ul style="list-style-type: none"> 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	<ul style="list-style-type: none"> 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. 	<ul style="list-style-type: none"> 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	<ul style="list-style-type: none"> 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. 	<ul style="list-style-type: none"> 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: <ul style="list-style-type: none"> 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. 	<ul style="list-style-type: none"> 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	<ul style="list-style-type: none"> Appropriately attenuated and treated water should be preferentially discharged to 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. 	<ul style="list-style-type: none"> Newly developed plots should be preferentially discharged to the Grand Union Canal, 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.
Water Recycling	Plot-scale commercial tenure greywater and roof water recycling	<ul style="list-style-type: none"> All new buildings with commercial tenures to deliver greywater and roof water recycling for non-potable use. 	<ul style="list-style-type: none"> 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 commercial properties to deliver plot-scale greywater and roof water recycling for non-potable use. This is likely to be particularly advantageous for industrial properties with large roof space and lower density of employees.

7 IWM Strategy Delivery

- 7.1.1.1 This section of the report considers how the various options identified within the described strategy scenarios 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.
- 7.1.1.2 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.
- 7.1.1.3 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.
- 7.1.1.4 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;
 - S106¹¹ / S278¹² 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.
- 7.1.1.5 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.

7.2 Key Delivery Considerations

- 7.2.1.1 There are a number of criteria that will need to be considered in the delivery of various aspects of the chosen 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.

7.2.2 Location

- 7.2.2.1 There are a number of potential 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.

¹¹ Town and Country Planning Act (1990)

¹² Highways Act (1980)

7.2.3 Scale of the works

- 7.2.3.1 Delivery of some of the proposed measures would require 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.

7.2.4 Timing of the works

- 7.2.4.1 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.

7.2.5 Cash flow for the works

- 7.2.5.1 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).

7.2.6 Potential for integrated infrastructure delivery

- 7.2.6.1 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.

7.2.7 Overall duration of the works

- 7.2.7.1 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.

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

- 7.2.8.1 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.

7.2.9 Nature of companies that can deliver the works

- 7.2.9.1 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.

7.3 Potential delivery approaches

- 7.3.1.1 Taking in to account all of the above factors, consideration has been given to the potential 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 be applicable across more than one of these options.

7.3.2 Surface water management

- 7.3.2.1 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.
- 7.3.2.2 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.

7.3.3 Strategic surface water network and attenuation

- 7.3.3.1 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.

- 7.3.3.2 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.
- 7.3.3.3 Downstream attenuation storages, should (where possible) be delivered by third parties rather than 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.
- 7.3.3.4 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 contributions to be made to the capital and operational costs of delivery.

7.3.4 Strategic Water Recycling Options

- 7.3.4.1 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 for commercial tenure, 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.
- 7.3.4.2 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.

8 Conclusions and Recommendations

- 8.1.1.1 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.
- 8.1.1.2 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.
- 8.1.1.3 Several potential strategy options were developed; all of which meet the core water objectives and therefore would allow development to proceed. 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).
- 8.1.1.4 A preferred strategy has been selected based on the technical infrastructure study developed alongside the latter stages of this IWMS. However, it is intended that the water management approach remains flexible and able to be adapted in line with the development proposals and the emerging masterplan as well as to allow future technological advancement to positively influence the eventual infrastructure delivery.
- 8.1.1.5 This IWMS has fed into the development of the Local Plan to ensure the aims and direction of the strategy are embedded in the plan making process, the development of water and flood risk policy, and the planning decision process.

8.2 Next Steps for Strategy Development

- 8.2.1.1 This strategy document and its findings are a core part of the detailed further assessment of the feasibility, development, and deliverability of water management and flood risk management measures. Further infrastructure development and delivery work has been taking place through 2016 and continues through 2017 as part of the Stage 2 infrastructure report as well as the utilities strategy and environmental standard setting for the Opportunity Area.
- 8.2.1.2 Several recommendations have been set out below for how this strategy which have informed the ongoing infrastructure delivery and policy setting work.

8.2.2 Recommendations for Further Assessment

- 8.2.2.1 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 further engagement with key stakeholders in order to confirm the suitability of discharge to this location.
 - 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 benefit in consider off-site attenuation in surrounding open spaces, such as Wormwood Scrubs.

- 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.

8.2.2.2 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.

The background of the page features three thin, dark grey lines that intersect to form a large, abstract geometric shape. One line runs diagonally from the top-left towards the bottom-right. Another line runs diagonally from the top-right towards the bottom-left. The third line runs diagonally from the middle-left towards the top-right. These lines create a series of triangular and quadrilateral regions across the page.

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 generation¹

	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

Opportunity Area Strategic Level 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.
- Demonstrate application of the Sequential Test, and where necessary the Exception Test, to the Opportunity Areas.

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	<p>LB Ealing (2008) http://www.ealing.gov.uk/downloads/download/564/ldf_evidence_base_strategic_flood_risk_assessment</p> <p>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/</p> <p>LB Hammersmith and Fulham http://www.lbhf.gov.uk/Images/LBHFSFRA_Final_tcm21-148443.pdf</p>
Local Flood Risk Management Strategy	<p>LB Ealing (draft, December 2014) http://www.ealing.gov.uk/download/downloads/id/9272/local_flood_risk_management_strategy_draft</p> <p>LB Brent (draft, July 2015) http://brent-consult.objective.co.uk/portal/ens/htdel/flood_risk_strategy_3?tab=files</p>
Preliminary Flood Risk	<p>LB Ealing (2011)</p> <p>LB Brent (2011)</p>

Evidence	Link
Assessment	LB Hammersmith and Fulham (2011) http://webarchive.nationalarchives.gov.uk/20140328084622/http://www.environment-agency.gov.uk/research/planning/135542.aspx#9
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_frmf/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) <ul style="list-style-type: none"> • 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	<ul style="list-style-type: none"> – 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: <ul style="list-style-type: none"> – 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. 	<ul style="list-style-type: none"> – 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	<ul style="list-style-type: none"> – No Source of flooding 	<ul style="list-style-type: none"> – No risk
Surface Water	<ul style="list-style-type: none"> – 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 	<ul style="list-style-type: none"> – 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
	<p>Chandos Road, flooded in August 2004.</p> <ul style="list-style-type: none"> – Critical Drainage Areas (CDAs) are located within the study area and detailed within this FRA, 	
Groundwater	<ul style="list-style-type: none"> – 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. 	<ul style="list-style-type: none"> – The majority of the Opportunity Area is underlain by the impermeable London Clay layer. The geological succession beneath the London Clay comprises:² <ul style="list-style-type: none"> – 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	<ul style="list-style-type: none"> – The PFRA and SFRA 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 Acton tube station. 	<ul style="list-style-type: none"> – 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

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)

Flood Source	Flooding Pathways & Historical Flooding	Summary of Risk
	<ul style="list-style-type: none"> – More widely, the LB Ealing SFRA notes the susceptibility and historical occurrence of flooding from overloaded 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. 	<p>and have been recorded in the 21- 50 range and 51-100 range respectively.³</p> <ul style="list-style-type: none"> – Sewer flood risk is considered to be moderate across within Park Royal and the south east section of Old Oak.
Artificial – Grand Union Canal	<ul style="list-style-type: none"> – 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 	<ul style="list-style-type: none"> – 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

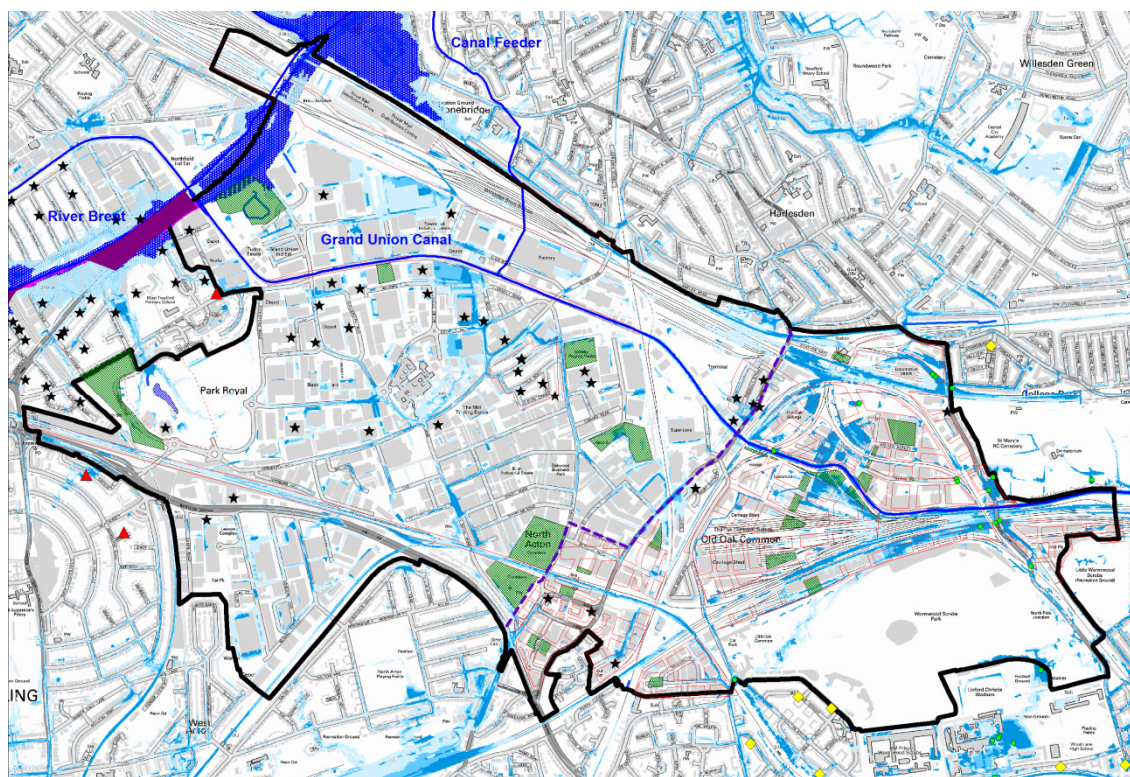
³ London West Midlands Environmental Statement Volume 5 | Technical Appendices CFA4 | Kilburn (Brent) to Old Oak Common Flood risk assessment (WR-003-004) (November 2013)

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
	<p>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 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.</p>	<p>order of approximately 0.2m–1m depending on the location of the assessment point, and the expected width of breach.</p> <ul style="list-style-type: none"> – Due to the management and maintenance of the canal and the limited extent of breach 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	<ul style="list-style-type: none"> – A dam break was experienced in the 1940's causing significant flooding apart from that incidence, due to a strict maintenance regime, only minor seepages and leakages have been reported. (Ealing SFRA) 	<ul style="list-style-type: none"> – 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:



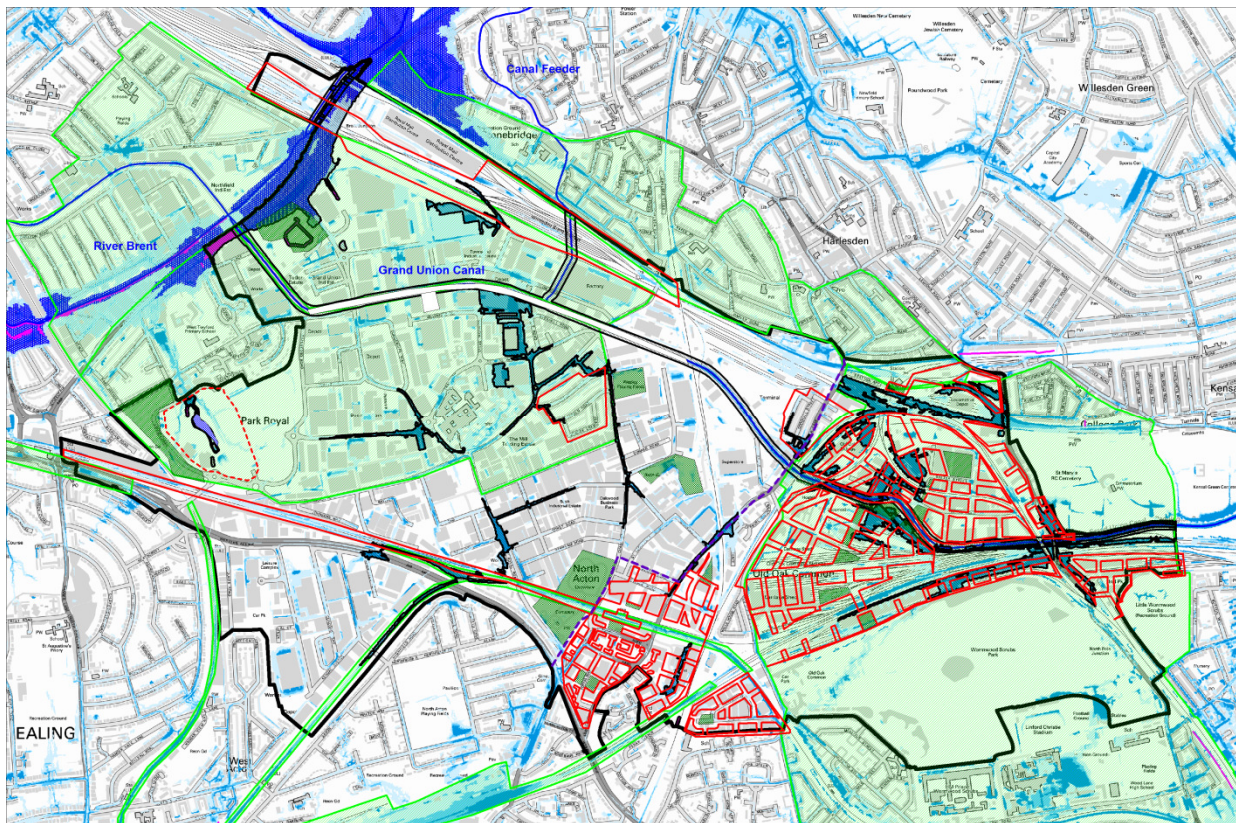
⁶ London West Midlands Environmental Statement Volume 5 | Technical Appendices CFA4 | Kilburn (Brent) to Old Oak Common Flood risk assessment (WR-003-004) (November 2013)

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 <i>Brent_10</i>	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 <i>Brent_09</i>	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.

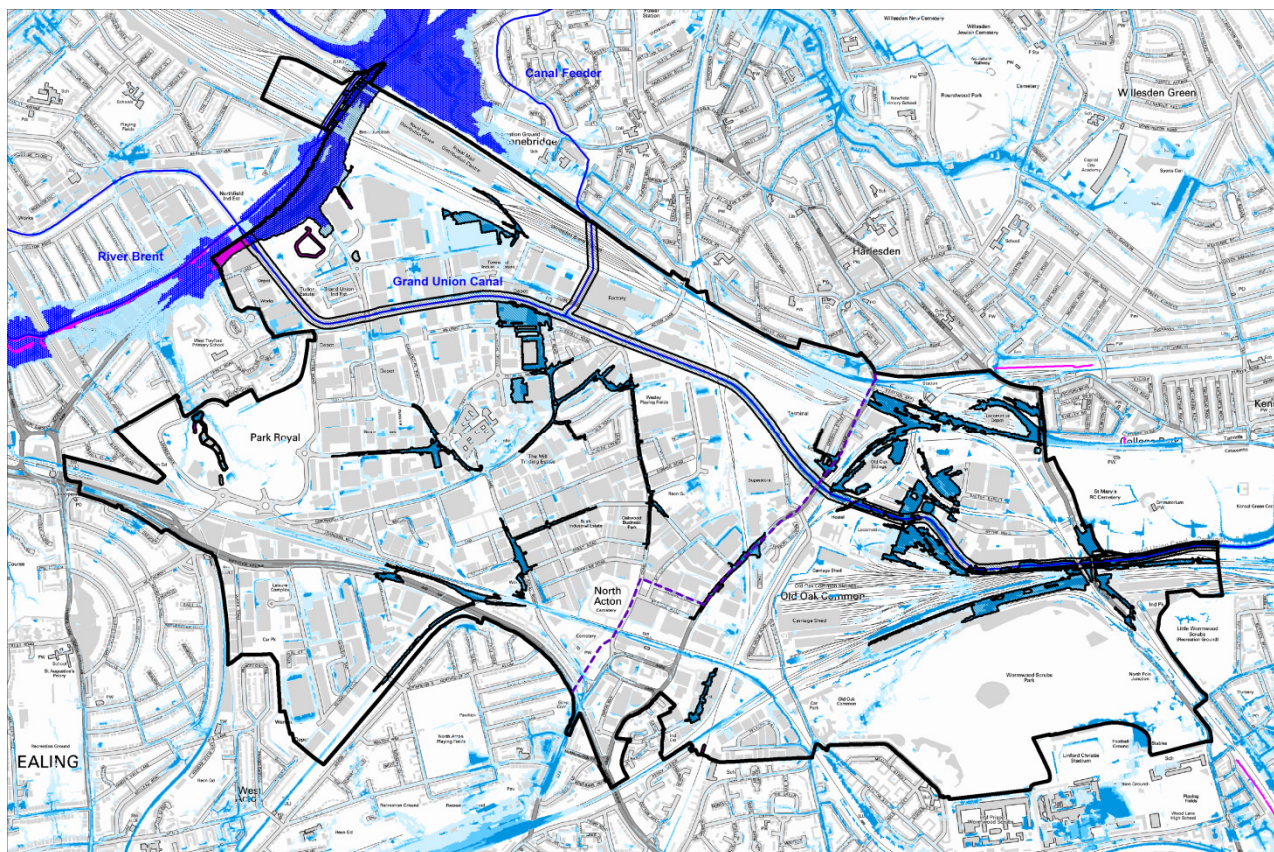
Figure C2: Location of Critical Drainage Areas (in green)

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.

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 7,100m³ 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.

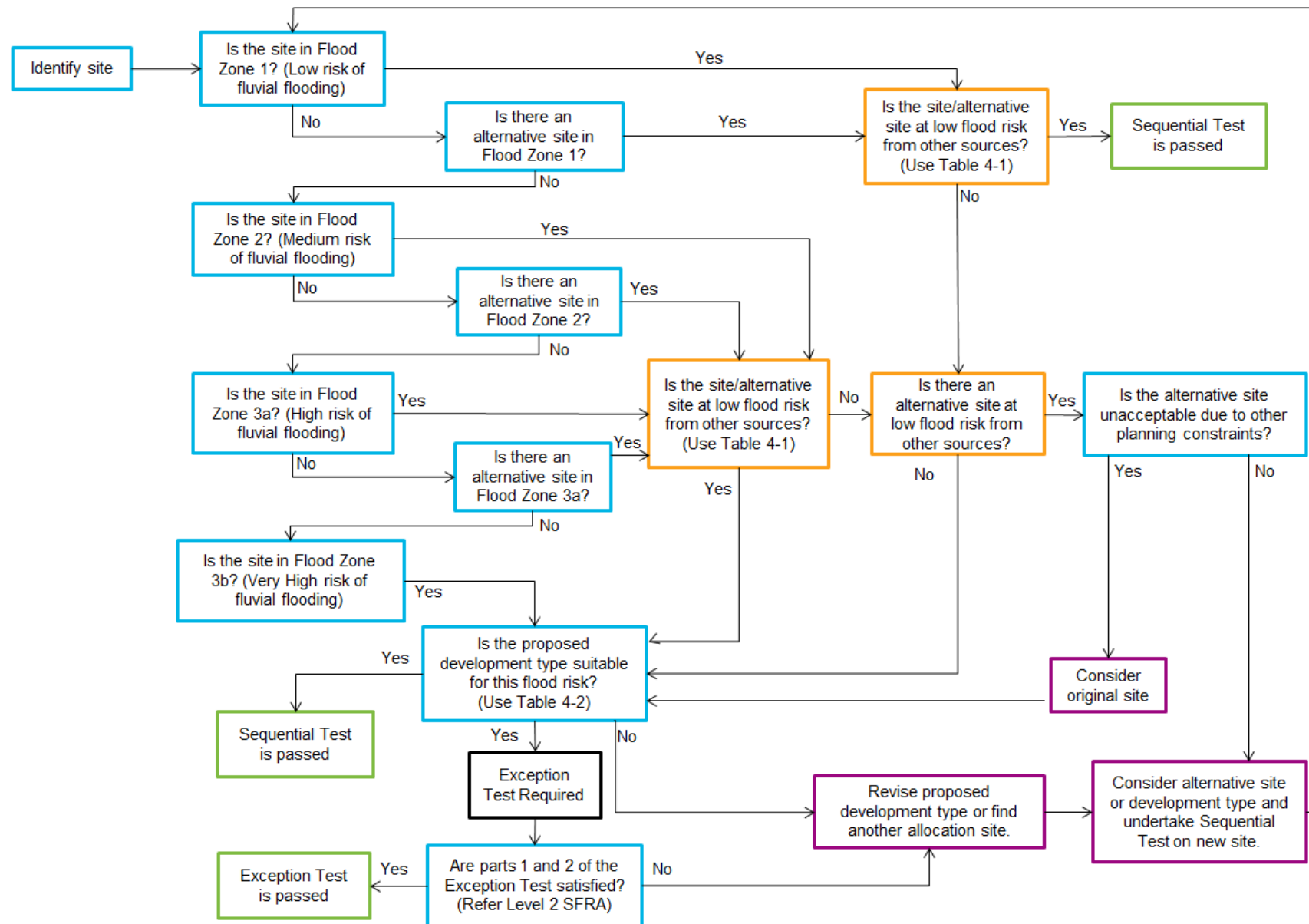
Application of the Sequential Test

This section outlines illustrates the application of the Sequential Test for the Old Oak and Park Royal Opportunity Area.

As the LPA, the OPDC must demonstrate that, throughout the site allocation process and related Sustainability Appraisal process, a range of possible sites have been considered in conjunction with the flood risk and vulnerability information set out in an appropriate SFRA , and that the Sequential Test, and where necessary, the Exception Test has been applied.

The Sequential Test, as set out in the NPPF, is principally based on the definition of Flood Zones associated with tidal and fluvial flood risk. However, the NPPF acknowledges that some areas will be at risk of flooding from sources other than tidal or fluvial. All sources of flood risk must be considered when planning for new development including: flooding from land or surface water runoff; groundwater; sewers; and artificial sources.

Figure C4 below outlines the approach used within this assessment for applying the Sequential Test for sites at risk flooding from different sources. Data presented in this Strategic-level Flood Risk Assessment (as drawn from several data sources, including the existing Borough's SFRAs) has been used to inform the process.

Figure C4 – The Sequential Test approach (all sources of flood risk)

Application of the Sequential Test

The Opportunity Area as a whole covers a large area and therefore sources of flood risk can vary between development locations. To assist in the application of the Sequential Test, the study area has been divided up into groups of development plots according to geographical location and evaluated at this finer level of resolution.

Old Oak Area Sequential Test

Development plots within the Old Oak section of the Opportunity Area have been divided into seven development locations; North of Grand Union Canal, South of Grand Union Canal, North of Wormwood Scrubs, East of Wormwood Scrubs, West of Wormwood Scrubs, North Acton and Area north of Central Line (Figure C5). Flood risk from all sources has been summarised for each area in Table C4. The West of Wormwood Scrubs development location indicates no risk of flooding from any source. The remainder of the development locations indicate a flood risk from surface water only.

Following the process outlined in Figure C4 above the Sequential Test is followed and detailed below.

West of Wormwood Scrubs:

- Is the site in Flood Zone 1? **Yes**
- Is the site/alternative site at low flood risk from other sources? **Yes**

Sequential Test is passed.

North of Canal, South of Canal, North of Wormwood Scrubs, East of Wormwood Scrubs, West of Wormwood Scrubs, North Action and, Area north of Central Line:

- Is the site in Flood zone 1? **Yes**
- Is the site/alternative site at low flood risk from other sources? **No (surface water flood risk)**
- Is there an alternative site at low flood risk from other sources? **No (see 'Justification for no alternative site within OA' below)**
- Is the proposed development suitable for this flood risk? **Yes**

Sequential Test is passed.

Justification for no alternative sites being available is provided after the presentation of the Sequential Test outcome for the Park Royal section of the Opportunity Area. Details on managing residual surface water flood risk is also presented.

Figure C5: Location map for development areas across the Opportunity Area

Table C4: Summary of flood risk to development locations within the Old Oak area

General development location	Proposed Use	NPPF vulnerability Classification	Predominant bedrock	Predominant Superficial geology	Flood Zone 2	Flood Zone 3	Area Benefitting defences?	Area tidal 3b?	Risk of flooding from Surface Water?
North of Grand Union Canal	Mixed	More vulnerable	London Clay	None	No	No	No	No	Flood mapping indicates risk of localised surface water flooding adjacent to railway embankment and next to the Grand Union Canal
South of Grand Union Canal	Mixed	More vulnerable	London Clay	None	No	No	No	No	Flood mapping indicates risk of localised surface water flooding adjacent to Grand Union Canal embankment.
North of Wormwood Scrubs	Mixed	More vulnerable	London Clay	None	No	No	No	No	Flood mapping indicates risk of localised surface water flooding along railway line towards the eastern extent of development parcel.
East of Wormwood Scrubs	Mixed	More vulnerable	London Clay	None	No	No	No	No	Flood mapping indicates risk of localised surface water flooding along railway line at the western extent of development parcel.
West of Wormwood Scrubs	Mixed	More vulnerable	London Clay	None	No	No	No	No	No
North Acton	Mixed	More vulnerable	London Clay	None	No	No	No	No	Flood mapping indicates risk of localised surface water flooding along Jenner Avenue.
Area north of Central Line	Mixed	More vulnerable	London Clay	None	No	No	No	No	Flood mapping indicates risk of localised surface water flooding along Victoria Road.

Park Royal Area Sequential Test

Development plots within Park Royal OA have been collated into three development locations; East of Central Middlesex Hospital, Adjacent to West Coast Mainline and, Adjacent to Central Line, (Figure**). The boundary for the Adjacent to West Coast Mainline development plot extends over the River Brent floodplain, however, no development is proposed in the floodplain and it has therefore been excluded from the analysis. Flood risk from all other sources has been summarised for each location in Table **.

Following the process outlined in Figure C4 above the Sequential Test will be followed and detailed below.

East of Central Middlesex Hospital, Adjacent to West Coast Mainline (excluding River Brent floodplain) and, Adjacent to Central Line:

- | | |
|--|-----------------------------------|
| - Is the site in Flood zone 1? | Yes |
| - Is the site/alternative site at low flood risk from other sources?
risk) | No (surface water flood |
| - Is there an alternative site at low flood risk from other sources?
no alternative site within OA' below) | No (see 'Justification for |
| - Is the proposed development suitable for this flood risk? | Yes |

Sequential Test is passed.

Table C5: Summary of flood risk to development locations within the Park Royal area

General development location	Proposed Use	NPPF vulnerability Classification	Predominant bedrock	Predominant Superficial geology	Flood Zone 2	Flood Zone 3	Area Benefitting defences?	Area tidal 3b?	Risk of flooding from Surface Water?
East of Central Middlesex Hospital	Mixed	More vulnerable	London Clay	None	No	No	No	No	Flood mapping indicates risk of surface water flooding along the edges of the development area along Harold Road and Wesley Avenue.
Adjacent to West Coast Mainline (excluding River Brent floodplain)	Mixed	More vulnerable	London Clay	Small area of Taplow Gravel Formation	No	No	No	No	Flood mapping indicates risk of surface water flooding along a low-lying branch railway.
Adjacent to Central Line	Mixed	More vulnerable	London Clay	None	No	No	No	No	Flood mapping indicates risk of localised surface water flooding along low-lying railway line

Justification for no alternative sites within the OA

The London Plan (2016) identifies Old Oak Common and Park Royal as Opportunity Areas. These two Opportunity Areas cover the entirety of the OPDC area. London Plan Policy 2.13 defines opportunity areas as “the capital’s major reservoir of brownfield land with significant capacity to accommodate new housing, commercial and other development linked to existing or potential improvements to public transport accessibility. Typically they can accommodate at least 5,000 jobs or 2,500 new homes or a combination of the two, along with other supporting facilities and infrastructure.”

The London Plan is supported by a Strategic Housing Land Availability Assessment (SHLAA). This looks to prioritise development in London onto the least constrained development sites, prioritising those sites that were ‘developable’ and ‘deliverable’ in accordance with the National Planning Policy Framework (NPPF). The process for this seeks also to prioritise development onto brownfield sites as opposed to greenfield sites, sites with higher public transport access and sites with less constraints. This includes the identification of whether the sites fell within an identified Flood Zone.

The Old Oak Common and Park Royal Opportunity Areas were deemed as appropriate for Opportunity Area status as a result of:

- The availability of brownfield land for development;
- The area’s current and planned future transport infrastructure making the area an appropriate location for optimised development; and
- The area not having as many constraints as other sites assessed as part of the SHLAA.

The principle of large-scale development within the OPDC area has therefore been set through the strategic policy direction in the London Plan (2016) and the matter for the Sequential Test within the OPDC area is to ensure that sites are prioritised according to their flood risk. However, for the development plots identified in figure C5 land not identified as development sites are either:

- Protected Strategic Industrial Locations (SIL);
- Designated open spaces;
- Transport infrastructure; or
- Residential communities.

There are therefore no appropriate alternative sites that could be identified through the Sequential Test. The Sequential Test must therefore focus on how to ensure that development mitigates the impacts of identified flooding risks.

Managing Residual Surface Water flood risk

The Sequential Test has utilised existing data sets with respect to surface water flood risk to the Opportunity Area. As part of this IWMS, measures are being proposed to manage and control surface water runoff to ensure that runoff is maintained as close to greenfield runoff rates as possible for all events up to the 1 in 100 year event with a 40% allowance for climate change. This will provide a significant betterment to surface water flood risk in the Opportunity Area and land surrounding it as surface water runoff controls within the current site usage are limited.

In addition, the Old Oak Opportunity Area will be subject to major restructuring, with significant ground level changes, new transport routes, and a major new HS2 station and hence there will be significant changes to the surface flow routes and areas of surface water ponding shown by current surface water flood risk mapping.

As part of the ongoing masterplanning for the Opportunity Area, wholesale surface water modelling will be undertaken, taking into account proposed measures for managing surface water in line with the requirements of this strategy (including an appropriate allowance for climate change as set out in the February 2016 guidance). This modelling will be used to refine design of SuDS and to design appropriate further resilience measures to development within Opportunity Area to manage the residual risk of surface water flooding appropriately.

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 programme⁷. 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 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 C6

Table C6: 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 West Acton	<p>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.</p> <p>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.</p> <p>Other measures that were considered include the "do nothing" scenario or provide flood storage within the railway corridor.</p>
	Group1_011	A40/A406 underpass, near Hanger Lane, Ealing	<p>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</p>

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
			<p>£500k.</p> <p>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.</p>
Brent	Group2_043 <i>Brent_10</i>	Park Royal	<p>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</p> <p>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.</p>
	Group2_042 <i>Brent_09</i>	North Circular	<p>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.</p> <p>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.</p>
Hammersmith & Fulham	Ward Area 1	College Park and Old Oak	<p>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.</p> <p>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 approximately 5,800m³ 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</p>

Borough	CDA	Location	Preferred Option
			<p>which the greatest volumes of surface water are retained.</p> <p>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.</p>

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 Scrubs⁸.

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.

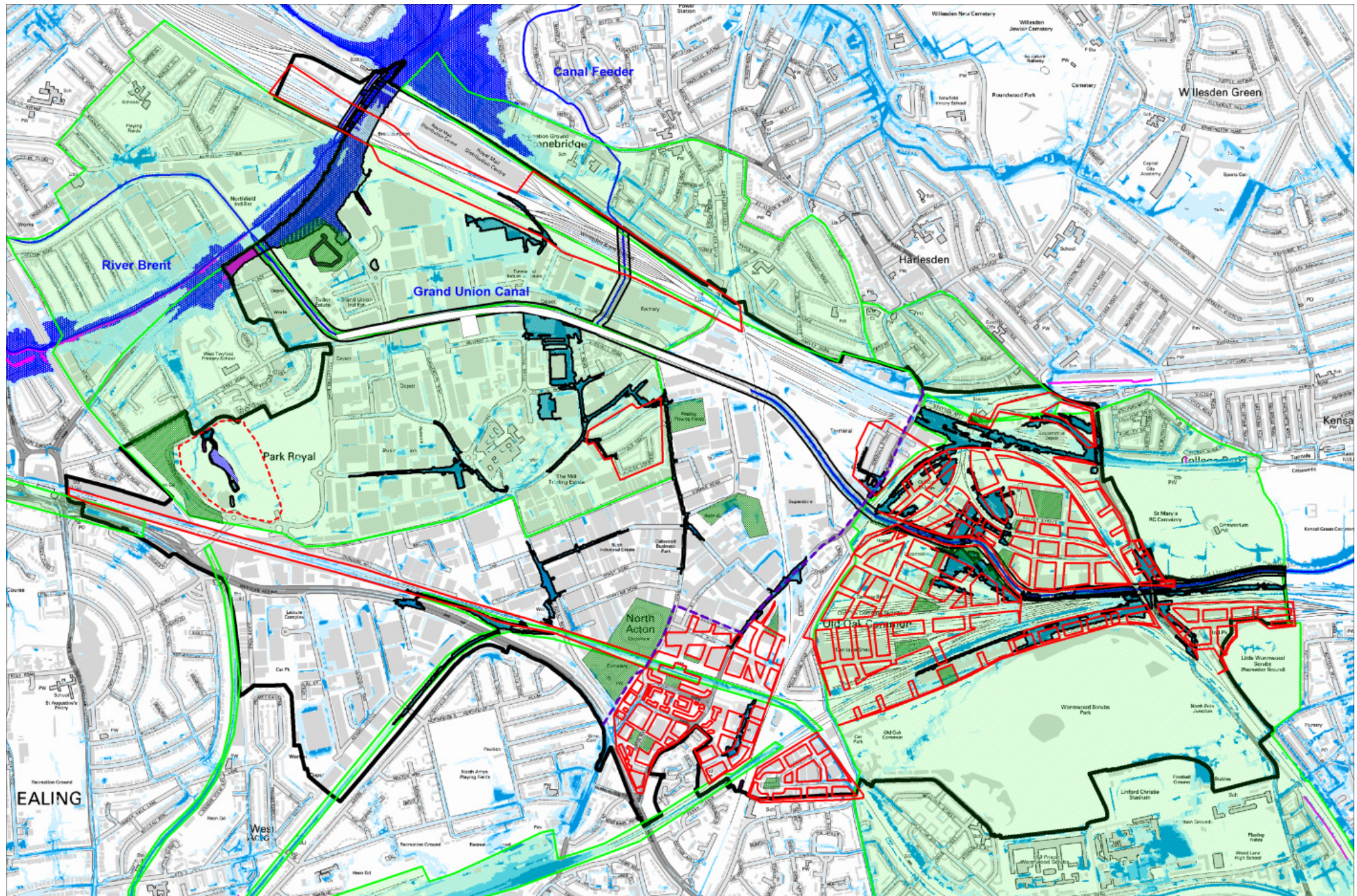
Potential Opportunities and Recommendations

- 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.

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

- 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.

Figure B5: Location map for development areas across the Opportunity Area



The background of the page features three thin, dark grey lines that intersect to form a large, irregular triangular shape. One line runs from the top left towards the bottom right, another runs from the top right towards the bottom left, and the third runs from the middle left towards the top right.

APPENDIX C

Plot Grouping Figures

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community



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

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



ISSUE/REVISION

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

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

Contains OS data © Crown copyright [and database right] (2015)

519000

520000

521000

522000

523000

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community



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
VR	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

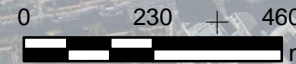
184000

183000

182000

181000


Contains OS data © Crown copyright [and database right] (2015)



The background of the page features three thin, dark grey lines that intersect to form a large, irregular triangular shape. One line runs from the top left towards the bottom right. Another line runs from the top right towards the bottom left. The third line runs from the middle left towards the top right. These lines create a complex geometric pattern across the white background.

APPENDIX D

Rainfall Runoff Calculations

AECOM Ltd		Page 1																																										
Aecom House 63-77 Victoria Street St Albans Herts AL1...	Old Oak Common and Park Royal Greenfield Run-off																																											
Date 26.10.2015 File Greenfield Run-o...	Designed by JHC Checked by MD																																											
XP Solutions	Source Control 2013.1.1																																											
<div>IH 124 Mean Annual Flood</div> <div>Input</div> <table><tr><td>Return Period (years)</td><td>100</td><td>Soil</td><td>0.450</td></tr><tr><td>Area (ha)</td><td>50.000</td><td>Urban</td><td>0.000</td></tr><tr><td>SAAR (mm)</td><td>633</td><td>Region Number</td><td>Region 6</td></tr></table> <div>Results l/s</div> <table><tr><td>QBAR Rural</td><td>195.3</td></tr><tr><td>QBAR Urban</td><td>195.3</td></tr><tr><td>Q100 years</td><td>622.9</td></tr><tr><td>Q1 year</td><td>166.0</td></tr><tr><td>Q2 years</td><td>172.0</td></tr><tr><td>Q5 years</td><td>249.9</td></tr><tr><td>Q10 years</td><td>316.3</td></tr><tr><td>Q20 years</td><td>391.2</td></tr><tr><td>Q25 years</td><td>419.4</td></tr><tr><td>Q30 years</td><td>442.5</td></tr><tr><td>Q50 years</td><td>511.6</td></tr><tr><td>Q100 years</td><td>622.9</td></tr><tr><td>Q200 years</td><td>732.2</td></tr><tr><td>Q250 years</td><td>767.4</td></tr><tr><td>Q1000 years</td><td>1007.6</td></tr></table>			Return Period (years)	100	Soil	0.450	Area (ha)	50.000	Urban	0.000	SAAR (mm)	633	Region Number	Region 6	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
Return Period (years)	100	Soil	0.450																																									
Area (ha)	50.000	Urban	0.000																																									
SAAR (mm)	633	Region Number	Region 6																																									
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																																											
©1982-2013 Micro Drainage Ltd																																												

Background Information

- ® High density development proposed across the Old Oak Common and Park Royal Opportunity Areas (OAs).
- ® The OAs have been split into several sub-areas.
- ® Calculation of attenuation required to restrict runoff to Greenfield rates, under the 1 in 100 year plus 40% Climate Change event.
- ® Micro drainage has been used to calculate the permitted Greenfield outflow, based on:
 - IHS 124 methodology
 - 50 hectare or greater catchment (l/s/hectare)
- ® M5-60 - M= how many years, 5= no. of years, 60= 60 min duration
- ® Grid coordinates obtained from www.streetmaps.co.uk

Old Oak Sub-Areas

Old Oak - Future	Total Area (ha)	Total Area (m²)	Area of Open Space (ha)	Area of Open Space (m²)	Impermeable (ha)	Impermeable (m²)	Easting/Northing	Lat/Lon
1	5.78	57800	2.41	24100	3.37	33700	522240, 183165	51.534,-0.239
2	4.39	43900	1.69	16900	2.7	27000	522450, 182534	51.528449,-0.236198
3	27.5	275000	13.76	137600	13.74	137400	521950, 182559	51.528782,-0.243394
4	6.51	65100	3.31	33100	3.2	32000	522660, 182364	51.526876,-0.233232
5	7.6	76000	3.03	30300	4.57	45700	521975, 182054	51.524238,-0.243208
6	31.36	313600	14.64	146400	16.72	167200	521495, 182234	51.525959,-0.250061
7	26.18	261800	15.5	155000	10.68	106800	521072, 182049	51.524387,-0.256219
8	6.71	67100	3.49	34900	3.22	32200	521299, 181609	51.520384,-0.253100

Old Oak - Existing	Total Area (ha)	Total Area (m²)	Area of Open Space (ha)	Area of Open Space (m²)	Impermeable (ha)	Impermeable (m²)
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



AECOM

PROJECT
OLD OAK COMMON
AND ROYAL PARK
DEVELOPMENT

CLIENT
OLD OAK COMMON
DEVELOPMENT
CORPORATION

CONSULTANT
AECOM Limited
1 The Quadrant, Basingstoke
Hampshire, RG24 0BA
www.aecom.com

LEGEND

- Plot Boundaries
- Old Oak Common - Plots

REVISIONS

NO.	DESCRIPTION	DATE

KEY PLAN

CONTRACT NUMBER
XXXXXXXXXX

SHEET TITLE
FIGURE 1
Old Oak Common - Plot Locations

Scale of A3: 1:5,000
SHEET NUMBER
1 of 1

Project: 60439696
 Ref: Old Oak Common and Park Royal IWMS
 Section: Old Oak Area 1

Made by: Lilian Gowans Date: 21 October 2015
 Updated by: Mel Davies Date: 18 November 2016
 Approved By: Jon Curry Date: 18 November 2016

DESIGN OF STORMWATER STORAGE FACILITY

Sizing of stormwater storage facility for Area 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 40% Climate change allowance

DURATION	Z1	M5-D	Z2	M100-D	M100-D plus CC
(minutes)		(M5-60 x Z1) (mm)		(M5-D x Z2) (mm)	R (M5-D x Z2) (mm)
5	0.38	7.98	1.86	14.9	20.8
10	0.53	11.13	1.93	21.5	30.0
15	0.63	13.23	1.96	26.0	36.3
30	0.80	16.80	2.00	33.7	47.1
60	1.00	21.00	2.03	42.5	59.6
120	1.20	25.20	2.01	50.6	70.9
240	1.40	29.40	1.97	58.1	81.3
360	1.50	31.50	1.96	61.7	86.3
600	1.70	35.70	1.92	68.7	96.2
1440	2.10	44.10	1.86	81.9	114.7
2880	2.45	51.45	1.80	92.6	129.7

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

Project: **60439696**
 Ref: **Old Oak Common and Park Royal IWMS**
 Section: **Old Oak Area 1**

Made by: **Lilian Gowans** Date: **21 October 2015**
 Updated by: **Mel Davies** Date: **18 November 2016**

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	INFLOW	OUTFLOW	REQUIRED STORAGE
(minutes)	(A x R) (m ³)	(a _{s50} x f x D) (m ³)	(I - O) (m ³)
5	701	13	688
10	1012	25	987
15	1224	38	1187
30	1589	76	1513
60	2007	152	1856
120	2388	303	2085
240	2739	607	2133
360	2910	910	2000
600	3241	1517	1725
1440	3864	3640	225
2880	4370	7279	0

Maximum Storage required

2133 m³

Project: 60439696
 Ref: Old Oak Common and Park Royal IWMS
 Section: Old Oak Area 2

Made by: Lilian Gowans Date: 21 October 2015
 Updated by: Mel Davies Date: 18 November 2016
 Approved By: Jon Curry Date: 18 November 2016

DESIGN OF STORMWATER STORAGE FACILITY

Sizing of stormwater storage facility for Area 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 40% *Climate change allowance*

DURATION	Z1	M5-D	Z2	M100-D	M100-D plus CC
(minutes)		(M5-60 x Z1) (mm)		(M5-D x Z2) (mm)	R (M5-D x Z2) (mm)
5	0.38	7.98	1.86	14.9	20.8
10	0.53	11.13	1.93	21.5	30.0
15	0.63	13.23	1.96	26.0	36.3
30	0.80	16.80	2.00	33.7	47.1
60	1.00	21.00	2.03	42.5	59.6
120	1.20	25.20	2.01	50.6	70.9
240	1.40	29.40	1.97	58.1	81.3
360	1.50	31.50	1.96	61.7	86.3
600	1.70	35.70	1.92	68.7	96.2
1440	2.10	44.10	1.86	81.9	114.7
2880	2.45	51.45	1.80	92.6	129.7

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

Project: **60439696**
 Ref: **Old Oak Common and Park Royal IWMS**
 Section: **Old Oak Area 2**

Made by: **Lilian Gowans** Date: **21 October 2015**
 Updated by: **Mel Davies** Date: **18 November 2016**

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	INFLOW	OUTFLOW	REQUIRED STORAGE
(minutes)	(A x R) (m ³)	(a _{s50} x f x D) (m ³)	(I - O) (m ³)
5	562	10	551
10	811	20	791
15	981	30	951
30	1273	61	1212
60	1608	122	1487
120	1913	243	1670
240	2195	486	1709
360	2331	729	1602
600	2597	1215	1382
1440	3096	2916	180
2880	3501	5832	0

Maximum Storage required

1709 m³

Project: 60439696
 Ref: Old Oak Common and Park Royal IWMS
 Section: Old Oak Area 3

Made by: Lilian Gowans Date: 21 October 2015
 Updated by: Mel Davies Date: 18 November 2016
 Approved By: Jon Curry Date: 18 November 2016

DESIGN OF STORMWATER STORAGE FACILITY

Sizing of stormwater storage facility for Area 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 40% *Climate change allowance*

DURATION	Z1	M5-D	Z2	M100-D	M100-D plus CC
(minutes)		(M5-60 x Z1) (mm)		(M5-D x Z2) (mm)	R (M5-D x Z2) (mm)
5	0.38	7.98	1.86	14.9	20.8
10	0.53	11.13	1.93	21.5	30.0
15	0.63	13.23	1.96	26.0	36.3
30	0.80	16.80	2.00	33.7	47.1
60	1.00	21.00	2.03	42.5	59.6
120	1.20	25.20	2.01	50.6	70.9
240	1.40	29.40	1.97	58.1	81.3
360	1.50	31.50	1.96	61.7	86.3
600	1.70	35.70	1.92	68.7	96.2
1440	2.10	44.10	1.86	81.9	114.7
2880	2.45	51.45	1.80	92.6	129.7

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

Project: **60439696**
 Ref: **Old Oak Common and Park Royal IWMS**
 Section: **Old Oak Area 3**

Made by: **Lilian Gowans** Date: **21 October 2015**
 Updated by: **Mel Davies** Date: **18 November 2016**

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	INFLOW	OUTFLOW	REQUIRED STORAGE
(minutes)	(A x R) (m ³)	(a _{s50} x f x D) (m ³)	(I - O) (m ³)
5	2857	52	2806
10	4128	103	4025
15	4992	155	4838
30	6478	309	6168
60	8184	618	7566
120	9736	1237	8499
240	11168	2473	8695
360	11864	3710	8154
600	13215	6183	7032
1440	15755	14839	916
2880	17816	29678	0

Maximum Storage required

8695 m³

Project: 60439696
 Ref: Old Oak Common and Park Royal IWMS
 Section: Old Oak Area 4

Made by: Lilian Gowans Date: 21 October 2015
 Updated by: Mel Davies Date: 18 November 2016
 Approved By: Jon Curry Date: 18 November 2016

DESIGN OF STORMWATER STORAGE FACILITY

Sizing of stormwater storage facility for Area 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 40% *Climate change allowance*

DURATION	Z1	M5-D	Z2	M100-D	M100-D plus CC R
(minutes)		(M5-60 x Z1) (mm)		(M5-D x Z2) (mm)	(M5-D x Z2) (mm)
5	0.38	7.98	1.86	14.9	20.8
10	0.53	11.13	1.93	21.5	30.0
15	0.63	13.23	1.96	26.0	36.3
30	0.80	16.80	2.00	33.7	47.1
60	1.00	21.00	2.03	42.5	59.6
120	1.20	25.20	2.01	50.6	70.9
240	1.40	29.40	1.97	58.1	81.3
360	1.50	31.50	1.96	61.7	86.3
600	1.70	35.70	1.92	68.7	96.2
1440	2.10	44.10	1.86	81.9	114.7
2880	2.45	51.45	1.80	92.6	129.7

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

Project: **60439696**
 Ref: **Old Oak Common and Park Royal IWMS**
 Section: **Old Oak Area 4**

Made by: **Lilian Gowans** Date: **21 October 2015**
 Updated by: **Mel Davies** Date: **18 November 2016**

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	INFLOW	OUTFLOW	REQUIRED STORAGE
(minutes)	(A x R) (m ³)	(a _{s50} x f x D) (m ³)	(I - O) (m ³)
5	666	12	654
10	961	24	937
15	1163	36	1127
30	1509	72	1437
60	1906	144	1762
120	2267	288	1979
240	2601	576	2025
360	2763	864	1899
600	3078	1440	1638
1440	3669	3456	213
2880	4149	6912	0

Maximum Storage required

2025 m³

Project: **60439696**
 Ref: **Old Oak Common and Park Royal IWMS**
 Section: **Old Oak Area 5**

Made by: **Lilian Gowans** Date: **21 October 2015**
 Updated by: **Mel Davies** Date: **18 November 2016**
 Approved By: **Jon Curry** Date: **18 November 2016**

DESIGN OF STORMWATER STORAGE FACILITY

Sizing of stormwater storage facility for Area 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 **40%** *Climate change allowance*

DURATION	Z1	M5-D	Z2	M100-D	M100-D plus CC R
(minutes)		(M5-60 x Z1) (mm)		(M5-D x Z2) (mm)	(M5-D x Z2) (mm)
5	0.38	7.98	1.86	14.9	20.8
10	0.53	11.13	1.93	21.5	30.0
15	0.63	13.23	1.96	26.0	36.3
30	0.80	16.80	2.00	33.7	47.1
60	1.00	21.00	2.03	42.5	59.6
120	1.20	25.20	2.01	50.6	70.9
240	1.40	29.40	1.97	58.1	81.3
360	1.50	31.50	1.96	61.7	86.3
600	1.70	35.70	1.92	68.7	96.2
1440	2.10	44.10	1.86	81.9	114.7
2880	2.45	51.45	1.80	92.6	129.7

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

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

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

Project: **60439696**
 Ref: **Old Oak Common and Park Royal IWMS**
 Section: **Old Oak Area 5**

Made by: **Lilian Gowans** Date: **21 October 2015**
 Updated by: **Mel Davies** Date: **18 November 2016**

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	INFLOW	OUTFLOW	REQUIRED STORAGE
(minutes)	(A x R) (m ³)	(a _{s50} x f x D) (m ³)	(I - O) (m ³)
5	950	17	933
10	1373	34	1339
15	1660	51	1609
30	2154	103	2052
60	2722	206	2516
120	3238	411	2827
240	3715	823	2892
360	3946	1234	2712
600	4395	2057	2339
1440	5240	4936	305
2880	5926	9871	0

Maximum Storage required

2892 m³

Project: **60439696**
 Ref: **Old Oak Common and Park Royal IWMS**
 Section: **Old Oak Area 6**

Made by: **Lilian Gowans** Date: **21 October 2015**
 Updated by: **Mel Davies** Date: **18 November 2016**
 Approved By: **Jon Curry** Date: **18 November 2016**

DESIGN OF STORMWATER STORAGE FACILITY

Sizing of stormwater storage facility for Area 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 **40%** *Climate change allowance*

DURATION	Z1	M5-D	Z2	M100-D	M100-D plus CC R
(minutes)		(M5-60 x Z1) (mm)		(M5-D x Z2) (mm)	(M5-D x Z2) (mm)
5	0.38	7.98	1.86	14.9	20.8
10	0.53	11.13	1.93	21.5	30.0
15	0.63	13.23	1.96	26.0	36.3
30	0.80	16.80	2.00	33.7	47.1
60	1.00	21.00	2.03	42.5	59.6
120	1.20	25.20	2.01	50.6	70.9
240	1.40	29.40	1.97	58.1	81.3
360	1.50	31.50	1.96	61.7	86.3
600	1.70	35.70	1.92	68.7	96.2
1440	2.10	44.10	1.86	81.9	114.7
2880	2.45	51.45	1.80	92.6	129.7

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

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

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

Project: **60439696**
 Ref: **Old Oak Common and Park Royal IWMS**
 Section: **Old Oak Area 6**

Made by: **Lilian Gowans** Date: **21 October 2015**
 Updated by: **Mel Davies** Date: **18 November 2016**

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
(minutes)	(A x R) (m ³)	(a _{s50} x f x D) (m ³)	(I - O) (m ³)
5	3477	63	3415
10	5023	125	4898
15	6075	188	5887
30	7882	376	7506
60	9959	752	9207
120	11847	1505	10342
240	13590	3010	10581
360	14437	4514	9923
600	16082	7524	8558
1440	19172	18058	1114
2880	21680	36115	0

Maximum Storage required

10581 m³

Project: **60439696**
 Ref: **Old Oak Common and Park Royal IWMS**
 Section: **Old Oak Area 7**

Made by: **Lilian Gowans** Date: **21 October 2015**
 Updated by: **Mel Davies** Date: **18 November 2016**
 Approved By: **Jon Curry** Date: **18 November 2016**

DESIGN OF STORMWATER STORAGE FACILITY

Sizing of stormwater storage facility for Area 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 **40%** *Climate change allowance*

DURATION	Z1	M5-D	Z2	M100-D	M100-D plus CC R
(minutes)		(M5-60 x Z1) (mm)		(M5-D x Z2) (mm)	(M5-D x Z2) (mm)
5	0.38	7.98	1.86	14.9	20.8
10	0.53	11.13	1.93	21.5	30.0
15	0.63	13.23	1.96	26.0	36.3
30	0.80	16.80	2.00	33.7	47.1
60	1.00	21.00	2.03	42.5	59.6
120	1.20	25.20	2.01	50.6	70.9
240	1.40	29.40	1.97	58.1	81.3
360	1.50	31.50	1.96	61.7	86.3
600	1.70	35.70	1.92	68.7	96.2
1440	2.10	44.10	1.86	81.9	114.7
2880	2.45	51.45	1.80	92.6	129.7

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

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

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

Project: **60439696**
 Ref: **Old Oak Common and Park Royal IWMS**
 Section: **Old Oak Area 7**

Made by: **Lilian Gowans**
 Updated by: **Mel Davies**

Date: **21 October 2015**
 Date: **18 November 2016**

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	INFLOW	OUTFLOW	REQUIRED STORAGE
(minutes)	(A x R) (m ³)	(a _{s50} x f x D) (m ³)	(I - O) (m ³)
5	2221	40	2181
10	3209	80	3129
15	3880	120	3760
30	5035	240	4795
60	6361	481	5881
120	7567	961	6606
240	8681	1922	6759
360	9222	2884	6338
600	10272	4806	5466
1440	12246	11534	712
2880	13848	23069	0

Maximum Storage required

6759 m³

Project: 60439696
 Ref: Old Oak Common and Park Royal IWMS
 Section: Old Oak Area 8

Made by: Lilian Gowans Date: 21 October 2015
 Updated by: Mel Davies Date: 18 November 2016
 Approved By: Jon Curry Date: 18 November 2016

DESIGN OF STORMWATER STORAGE FACILITY

Sizing of stormwater storage facility for Area 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 40% Climate change allowance

DURATION	Z1	M5-D	Z2	M100-D	M100-D plus CC R
(minutes)		(M5-60 x Z1) (mm)		(M5-D x Z2) (mm)	(M5-D x Z2) (mm)
5	0.38	7.98	1.86	14.9	20.8
10	0.53	11.13	1.93	21.5	30.0
15	0.63	13.23	1.96	26.0	36.3
30	0.80	16.80	2.00	33.7	47.1
60	1.00	21.00	2.03	42.5	59.6
120	1.20	25.20	2.01	50.6	70.9
240	1.40	29.40	1.97	58.1	81.3
360	1.50	31.50	1.96	61.7	86.3
600	1.70	35.70	1.92	68.7	96.2
1440	2.10	44.10	1.86	81.9	114.7
2880	2.45	51.45	1.80	92.6	129.7

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

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

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

Project: 60439696
 Ref: Old Oak Common and Park Royal IWMS
 Section: Old Oak Area 8

Made by:	Lilian Gowans	Date:	21 October 2015
Updated by:	Mel Davies	Date:	18 November 2016
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	INFLOW	OUTFLOW	REQUIRED STORAGE
(minutes)	(A x R) (m ³)	(a _{s50} x f x D) (m ³)	(I - O) (m ³)
5	670	12	658
10	967	24	943
15	1170	36	1134
30	1518	72	1446
60	1918	145	1773
120	2282	290	1992
240	2617	580	2038
360	2780	869	1911
600	3097	1449	1648
1440	3692	3478	215
2880	4175	6955	0

Maximum Storage required

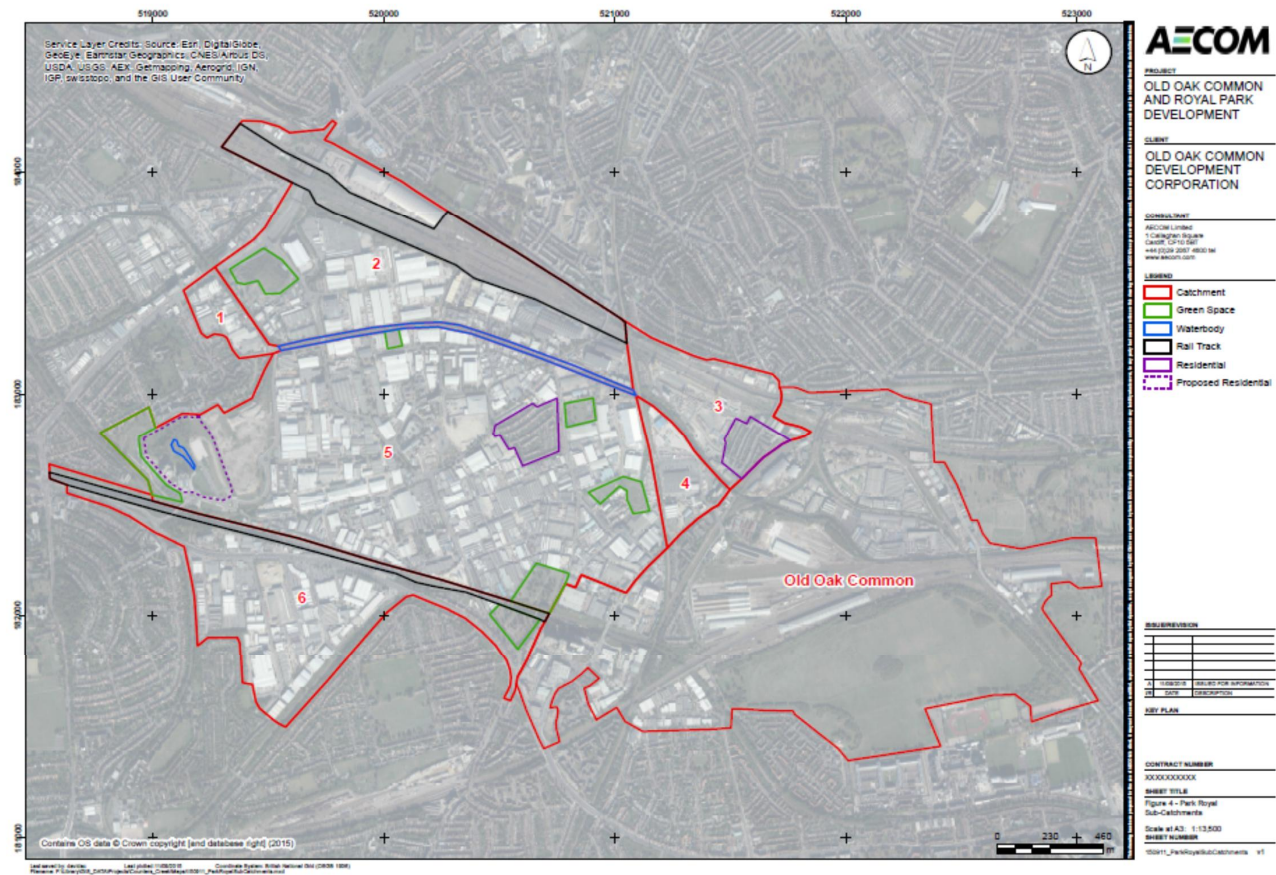
2038 m³

Total Storage Required for Old Oak

Sun-Area	Maximum Storage Required (m³)
1	2133
2	1709
3	8695
4	2025
5	2892
6	10581
7	6759
8	2038
Total	36831

Park Royal Sub-Areas

Sub Area	Plots (m²)	Plots (ha)	Easting/Northing	Lat/Lon
1	75,143.28	7.51	519194, 183419	51.537099,-0.282813
2	986,702.09	98.67	519489, 183674	51.539328,-0.278475
3	274,061.19	27.41	521434, 182969	51.532578,-0.250687
4	115,942.43	11.59	521284, 182669	51.529914,-0.252952
5	1,967,278.15	196.73	520834, 182887	51.531969,-0.259361
6	703,181.41	70.32	520306, 182047	51.524533,-0.267256



Project: **60439696**
 Ref: **Old Oak Common and Park Royal IWMS**
 Section: **Park Royal Area 1**

Made by: **Lilian Gowans** Date: **21 October 2015**
 Updated by: **Mel Davies** Date: **18 November 2016**
 Approved By: **Jon Curry** Date: **18 November 2016**

DESIGN OF STORMWATER STORAGE FACILITY

Sizing of stormwater storage facility for Area 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 **40%** *Climate change allowance*

DURATION	Z1	M5-D	Z2	M100-D	M100-D plus CC
(minutes)		(M5-60 x Z1) (mm)		(M5-D x Z2) (mm)	R (M5-D x Z2) (mm)
5	0.38	7.98	1.86	14.9	20.8
10	0.53	11.13	1.93	21.5	30.0
15	0.63	13.23	1.96	26.0	36.3
30	0.80	16.80	2.00	33.7	47.1
60	1.00	21.00	2.03	42.5	59.6
120	1.20	25.20	2.01	50.6	70.9
240	1.40	29.40	1.97	58.1	81.3
360	1.50	31.50	1.96	61.7	86.3
600	1.70	35.70	1.92	68.7	96.2
1440	2.10	44.10	1.86	81.9	114.7
2880	2.45	51.45	1.80	92.6	129.7

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
(minutes)	(A x R) (m ³)	(a _{s50} x f x D) (m ³)	(I - O) (m ³)
5	1563	28	1535
10	2258	56	2201
15	2730	85	2646
30	3543	169	3373
60	4476	338	4138
120	5324	676	4648
240	6108	1353	4755
360	6488	2029	4460
600	7227	3381	3846
1440	8616	8115	501
2880	9743	16231	0

Maximum Storage required

4755 m³

Project: **60439696**
 Ref: **Old Oak Common and Park Royal IWMS**
 Section: **Park Royal Area 2**

Made by: **Lilian Gowans** Date: **21 October 2015**
 Updated by: **Mel Davies** Date: **18 November 2016**
 Approved By: **Jon Curry** Date: **18 November 2016**

DESIGN OF STORMWATER STORAGE FACILITY

Sizing of stormwater storage facility for Area 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

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 40% Climate change allowance

DURATION	Z1	M5-D	Z2	M100-D	M100-D plus CC
(minutes)		(M5-60 x Z1) (mm)		(M5-D x Z2) (mm)	R (M5-D x Z2) (mm)
5	0.38	7.98	1.86	14.9	20.8
10	0.53	11.13	1.93	21.5	30.0
15	0.63	13.23	1.96	26.0	36.3
30	0.80	16.80	2.00	33.7	47.1
60	1.00	21.00	2.03	42.5	59.6
120	1.20	25.20	2.01	50.6	70.9
240	1.40	29.40	1.97	58.1	81.3
360	1.50	31.50	1.96	61.7	86.3
600	1.70	35.70	1.92	68.7	96.2
1440	2.10	44.10	1.86	81.9	114.7
2880	2.45	51.45	1.80	92.6	129.7

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	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
(minutes)	(A x R) (m ³)	(a _{s50} x f x D) (m ³)	(I - O) (m ³)
5	20520	370	20150
10	29644	740	28904
15	35851	1110	34741
30	46517	2220	44296
60	58772	4440	54332
120	69914	8880	61034
240	80202	17761	62441
360	85200	26641	58559
600	94902	44402	50501
1440	113139	106564	6575
2880	127940	213128	0

Maximum Storage required

62441 m³

Project: **60439696**
 Ref: **Old Oak Common and Park Royal IWMS**
 Section: **Park Royal Area 3**

Made by: **Lilian Gowans** Date: **21 October 2015**
 Updated by: **Mel Davies** Date: **18 November 2016**
 Approved By: **Jon Curry** Date: **18 November 2016**

DESIGN OF STORMWATER STORAGE FACILITY Sizing of stormwater storage facility for Area 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	40%	Climate change allowance

DURATION	Z1	M5-D	Z2	M100-D	M100-D plus CC
(minutes)		(M5-60 x Z1) (mm)		(M5-D x Z2) (mm)	R (M5-D x Z2) (mm)
5	0.38	7.98	1.86	14.9	20.8
10	0.53	11.13	1.93	21.5	30.0
15	0.63	13.23	1.96	26.0	36.3
30	0.80	16.80	2.00	33.7	47.1
60	1.00	21.00	2.03	42.5	59.6
120	1.20	25.20	2.01	50.6	70.9
240	1.40	29.40	1.97	58.1	81.3
360	1.50	31.50	1.96	61.7	86.3
600	1.70	35.70	1.92	68.7	96.2
1440	2.10	44.10	1.86	81.9	114.7
2880	2.45	51.45	1.80	92.6	129.7

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	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
(minutes)	(A x R) (m ³)	(a _{s50} x f x D) (m ³)	(I - O) (m ³)
5	5700	103	5597
10	8234	206	8028
15	9958	308	9649
30	12920	617	12304
60	16324	1233	15091
120	19419	2467	16952
240	22276	4933	17343
360	23665	7400	16265
600	26360	12333	14027
1440	31425	29599	1826
2880	35536	59197	0

Maximum Storage required

17343 m³

Project: **60439696**
 Ref: **Old Oak Common and Park Royal IWMS**
 Section: **Park Royal Area 4**

Made by: **Lilian Gowans** Date: **21 October 2015**
 Updated by: **Mel Davies** Date: **18 November 2016**
 Approved By: **Jon Curry** Date: **18 November 2016**

DESIGN OF STORMWATER STORAGE FACILITY Sizing of stormwater storage facility for Area 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 <i>(interpolated)</i>	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	<i>From Wallingford Procedure, Volume 3; Maps. Rainfall depth (M5-60 minutes)</i>
r	0.43	<i>From Wallingford Procedure, Volume 3; Maps. Ratio of M5-60 minutes to M5-two day rainfall</i>
CC	40%	<i>Climate change allowance</i>

DURATION	Z1	M5-D	Z2	M100-D	M100-D plus CC
(minutes)		(M5-60 x Z1) (mm)		(M5-D x Z2) (mm)	R (M5-D x Z2) (mm)
5	0.38	7.98	1.86	14.9	20.8
10	0.53	11.13	1.93	21.5	30.0
15	0.63	13.23	1.96	26.0	36.3
30	0.80	16.80	2.00	33.7	47.1
60	1.00	21.00	2.03	42.5	59.6
120	1.20	25.20	2.01	50.6	70.9
240	1.40	29.40	1.97	58.1	81.3
360	1.50	31.50	1.96	61.7	86.3
600	1.70	35.70	1.92	68.7	96.2
1440	2.10	44.10	1.86	81.9	114.7
2880	2.45	51.45	1.80	92.6	129.7

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	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
(minutes)	(A x R) (m ³)	(a _{s50} x f x D) (m ³)	(I - O) (m ³)
5	2411	43	2368
10	3483	87	3396
15	4213	130	4082
30	5466	261	5205
60	6906	522	6384
120	8215	1043	7172
240	9424	2087	7337
360	10011	3130	6881
600	11152	5217	5934
1440	13294	12522	773
2880	15034	25044	0

Maximum Storage required

7337 m³

Project: **60439696**
 Ref: **Old Oak Common and Park Royal IWMS**
 Section: **Park Royal Area 5**

Made by: **Lilian Gowans** Date: **21 October 2015**
 Updated by: **Mel Davies** Date: **18 November 2016**
 Approved By: **Jon Curry** Date: **18 November 2016**

DESIGN OF STORMWATER STORAGE FACILITY

Sizing of stormwater storage facility for Area 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	40%	Climate change allowance

DURATION	Z1	M5-D	Z2	M100-D	M100-D plus CC
(minutes)		(M5-60 x Z1) (mm)		(M5-D x Z2) (mm)	R (M5-D x Z2) (mm)
5	0.38	7.98	1.86	14.9	20.8
10	0.53	11.13	1.93	21.5	30.0
15	0.63	13.23	1.96	26.0	36.3
30	0.80	16.80	2.00	33.7	47.1
60	1.00	21.00	2.03	42.5	59.6
120	1.20	25.20	2.01	50.6	70.9
240	1.40	29.40	1.97	58.1	81.3
360	1.50	31.50	1.96	61.7	86.3
600	1.70	35.70	1.92	68.7	96.2
1440	2.10	44.10	1.86	81.9	114.7
2880	2.45	51.45	1.80	92.6	129.7

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	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	INFLOW	OUTFLOW	REQUIRED STORAGE
(minutes)	(A x R) (m ³)	(a _{s50} x f x D) (m ³)	(I - O) (m ³)
5	40913	738	40176
10	59104	1475	57628
15	71480	2213	69266
30	92744	4426	88318
60	117180	8853	108327
120	139394	17706	121689
240	159906	35411	124495
360	169870	53117	116754
600	189216	88528	100688
1440	225575	212466	13109
2880	255085	424932	0

Maximum Storage required

124495 m³

Project: **60439696**
 Ref: **Old Oak Common and Park Royal IWMS**
 Section: **Park Royal Area 6**

Made by: **Lilian Gowans** Date: **21 October 2015**
 Updated by: **Mel Davies** Date: **18 November 2016**
 Approved By: Date:

DESIGN OF STORMWATER STORAGE FACILITY

Sizing of stormwater storage facility for Area 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	40%	Climate change allowance

DURATION	Z1	M5-D	Z2	M100-D	M100-D plus CC
(minutes)		(M5-60 x Z1) (mm)		(M5-D x Z2) (mm)	(M5-D x Z2) (mm)
5	0.38	7.98	1.86	14.9	20.8
10	0.53	11.13	1.93	21.5	30.0
15	0.63	13.23	1.96	26.0	36.3
30	0.80	16.80	2.00	33.7	47.1
60	1.00	21.00	2.03	42.5	59.6
120	1.20	25.20	2.01	50.6	70.9
240	1.40	29.40	1.97	58.1	81.3
360	1.50	31.50	1.96	61.7	86.3
600	1.70	35.70	1.92	68.7	96.2
1440	2.10	44.10	1.86	81.9	114.7
2880	2.45	51.45	1.80	92.6	129.7

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	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
(minutes)	(A x R) (m ³)	(a _{s50} x f x D) (m ³)	(I - O) (m ³)
5	14624	264	14360
10	21126	527	20599
15	25550	791	24758
30	33150	1582	31568
60	41885	3164	38720
120	49825	6329	43496
240	57157	12657	44499
360	60718	18986	41732
600	67633	31643	35990
1440	80629	75944	4686
2880	91177	151887	0

Maximum Storage required

44499 m³

Total Storage Required for Park Royal

Sub-Area	Maximum Storage Required (m³)	
	1	4755
	2	62441
	3	17343
	4	7337
	5	124495
	6	44499
Total		260871

