# Technical Appendix D: Option Details and Case Studies

## 1 Introduction

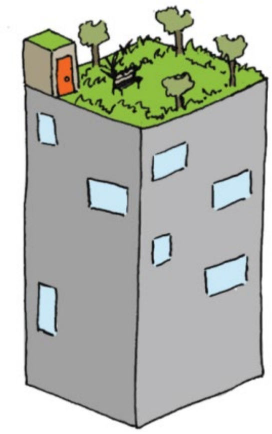
The purpose of this Technical Appendix is to provide further details on some of the study-wide water management options identified in the IWMP, as well as a range of case studies demonstrating examples of option delivery. The following options are described:

- Section 2 – SuDS Types
- Section 3 – SuDS and Urban Greening
- Section 4 – Water Re-Use

# 2 SuDS Types

The section gives further details on different SuDS types which could be adopted including generic Red, Amber Green (RAG) rating for key criteria related to their benefits or disbenefits.

## 2.1 Green or Blue Roofs



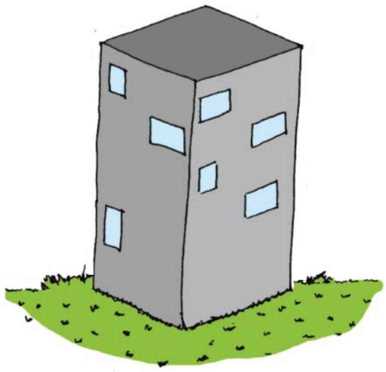
Green roofs consist of a planted soil layer, constructed on the roof of a building to create a living surface. The vegetated substrate is generally built on top of a drainage layer. Following rainfall, water is stored in the soil layer and absorbed by vegetation. Green roofs may be designed and constructed to be accessible and landscaped to provide biodiversity and community benefit. In many cases, it may be beneficial to combine vegetated roofs with roof water collection storages, known as blue roofs, where the stored water can be used to provide an additional balancing irrigation supply for vegetation. Combined blue-green roofs can optimise outcomes by providing blue roof storage beneath a green roof layer.

Green and blue roofs may be constructed on new buildings, or retrofitted onto existing surfaces, although, in some cases there will be restrictions on the ability to retrofit due to inadequate structural capacity or overly sloping surfaces and retrofit is likely to be more expensive.

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 impermeable surface will also provide benefits in reducing the speed of runoff and providing water quality benefits through filtration and bio-retention. Green roofs will only perform attenuation functions until they reach saturation. Living walls and green facades may also be suitable for installation and provide similar functions and benefits as green roofs.

| **Issue** | **RAG Rating for Benefits or Disbenefits** |
|---|---|
| Spatial Requirements | *Low requirement - No additional land take* |
| Maintenance Requirements | *Low input required* - irrigation required during establishment of vegetation, ongoing inspection and monitoring of vegetation cover, removal of litter or debris. |
| Regulatory and Public Acceptability | *High acceptability* - supported by current planning policy and potential to provide recreational and amenity benefit |
| Flexibility and scalability | *High flexibility* - ability for gradual implementation as development progresses. Limitations for retrofit on existing buildings, due to inadequate structural composition or overly sloping surfaces. |
| Carbon Intensity | *Low intensity*- potential for carbon sequestration and building insulation, with reduced associated energy requirements. |
| Blue-Green Space provided | *High provision*- 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 resilience*- 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 benefit* - vegetated system reducing the quantity and the speed of runoff and providing water quality benefits through filtration and bio-retention. |

## 2.2 Permeable Surfacing



Maximising permeable surfaces can increase the amount of water that is attenuated, treated and processed within the natural hydrological cycle. This can be achieved through maximising natural grassed surfaces or through hardscape solutions, such as permeable paving.

These measures are generally designed to promote infiltration of runoff into the ground beneath, promoting recharge of the water table and reducing runoff. This is highly beneficial where possible; however, contaminated land or soils with poor infiltration characteristics may present constraints in certain locations. Particularly within the study area and would require ground investigations and infiltration testing to confirm the acceptability.

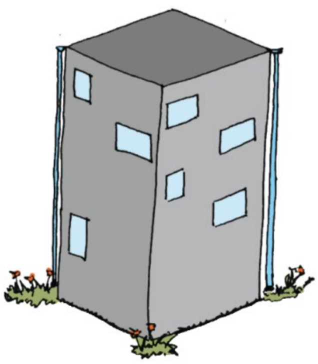
In these locations, where direct infiltration of surface water is not possible, lined permeable paving can also be used to provide attenuation and filtration of surface water.

Permeable paving is likely to be suitable for the development areas, as a spatially-effective means of providing multi-functional attenuation. A range of finishes are available. This is also likely to be suitable for streetscape areas, and may be retrofit into retained development areas.

| **Issue** | **RAG Rating for Benefits or Disbenefits** |
|---|---|
| Spatial Requirements | *Low requirement* – No additional land take. |
| Maintenance Requirements | *Medium requirement* - Regular inspection and maintenance, including removal of litter and debris and vegetation management. |
| Regulatory and Public Acceptability | *High acceptability* - Supported by current planning policy and able to be incorporated in low impact and multi-functional installations. |
| Flexibility and scalability | *Highly flexible* - Scalable, with the ability for gradual implementation. |
| Carbon Intensity | *Medium intensity* – Similar to non-permeable surface installations. |
| Blue-Green Space provided | *None* |
| Climate Resilience | *Medium resilience* - 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 benefit* - Facilitates infiltration and some filtration of surface water flows. |

## 2.3 Bio-retention Systems

Bio-retention systems are shallow landscaped and vegetated areas which harness on engineered soils, enhanced vegetation and filtration to remove pollution and reduce runoff downstream.



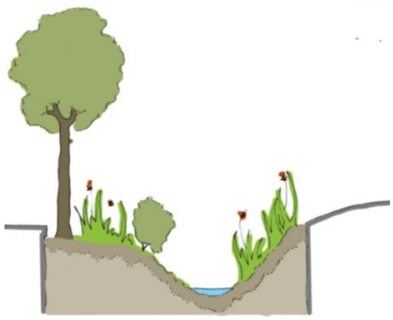
Rain gardens and tree pits both form a bio-retention function. As such, incorporating such features within the development can assist in absorbing runoff generated within the development, reducing flooding, improving water quality, providing irrigation for vegetation and enhancing amenity value.

Incorporation of these measures will also contribute towards providing the required attenuation storage. Where possible, these measures are designed to promote infiltration of runoff into the ground beneath, promoting recharge of the water table and reducing runoff; however, contaminated land or soils with poor infiltration characteristics may present constraints in certain locations.

Bio-retention features have the potential to provide substantial benefit to the development area and are likely to be particularly suitable where integrated into landscaping and tree planting proposals. These features can also be retrofitted into retained developed areas in a cost-effective way, providing a range of benefits to the urban environment.

| **Issue** | **RAG Rating for Benefits or Disbenefits** |
|---|---|
| Spatial Requirements | *Medium requirement* - Reasonable surface spatial requirements, however, this may be integrated within site landscaping and delivered to provide multiple benefits, |
| Maintenance Requirements | *Medium requirement* - Regular inspection and maintenance, including removal of litter and debris and vegetation management. |
| Regulatory and Public Acceptability | *High acceptability* - Supported by current planning policy and potential to provide recreational and amenity benefit. |
| Flexibility and scalability | *Highly scalable* - Scalable, with the ability for gradual implementation. |
| Carbon Intensity | *Low intensity* - Potential for carbon sequestration. |
| Blue-Green Space provided | *High provision* - 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 | *High resilience* - 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 benefit* - Vegetated systems providing water quality benefits through filtration and bio-retention. |

## 2.4 Strategic SuDS Networks



Where space permits, a strategic surface water network could be implemented within some parts of the study area, particularly for development post 2031 and where green corridors are located within and between development plots. Such systems 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 and filter strips. 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. Due to spatial requirements, these solutions must be considered early in the planning process. 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 the balance of on-plot to downstream attenuation.

The design and configuration of strategic networks would require detailed consideration of spatial availability and constraints, topography, water quality and discharge. The overall feasibility and extent of such features would be highly dependent on spatial availability. Desirably, new street networks and green spaces 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. Spatial availability, topographical fragmentation and existing infrastructure should all be considered with respect to constraints on the delivery of strategic networks.

| **Issue** | **RAG Rating for Benefits or Disbenefits** |
|---|---|
| Spatial Requirements | *High requirement* - reasonable surface spatial requirements, which will be difficult to incorporate into the dense development areas, and particularly challenging to retrofit in existing areas. However, where possible, this may be integrated within site landscaping and delivered to provide multiple benefits. |
| Maintenance Requirements | *Medium requirement* - 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 acceptability*- multi-functional infrastructure can enhance the streetscape and public realm. Determining responsibility for ongoing maintenance may present some barriers. |
| Flexibility and scalability | *Medium scalability* - 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. |
| Carbon Intensity | *Low intensity* - maximises passive conveyance and treatment by harnessing natural catchment hydrology. Potential for carbon sequestration. |
| Blue-Green Space provided | *High provision* - 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 resilience* - 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 benefit* - 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. |

# 3 SuDS and Urban Greening

The use of SuDS features to store, convey and filter water in the urban environment is now an expected component of any new development. However, the multiple benefits that can be delivered through 'soft' SuDS is not always recognised.

## 3.1 Definition of 'Soft' SuDS

*Above ground attenuation and conveyancing features that retain water at the surface (either permanently or following rainfall events) and are composed of 'soft' landscape materials such as wildflower grasses, herbaceous planting, shrubs and trees. 'Soft' SuDS features offer opportunities for filtering of pollutants without the needs for mechanical interceptors and are cheaper and easier to maintain than traditional drainage systems, as they can be accessed from the surface and require landscape operations, rather than complex engineering operations. Additional benefits of soft SuDS include increased biodiversity and amenity/provision of green space.*

In dense urban areas, where land availability is in short supply the use of rills and rain gardens can provide attenuation and conveyancing that also contributes to biodiversity and urban greening.

**Plate 1: Streetside rill, London. Source: www.flickr.com Thames 21 (CC BY-ND 2.0)**

**Plate 2: Rain Garden. Source: www.flickr.com susdrain (Public Domain Mark 1.0)**

The creation of 'Soft' SuDS features on podium decks is now possible through crated/tank solutions and provides opportunities for rainwater storage/harvesting as well as attenuation. Planted attenuation features work alongside crated storage systems to offer multiple benefits in the form of biodiversity net gain, urban greening and public open space. Decked car parking can also be provided, and green space reduces the urban heat island effect. Green spaces also promote health and wellbeing through provision of valuable outside green space in densely populated urban housing sites



**Plate 3: Orly Square, Amsterdam – crated podium**

**Plate 4: Orly Square, Amsterdam – planted areas**

Source: www.permavoid.co.uk

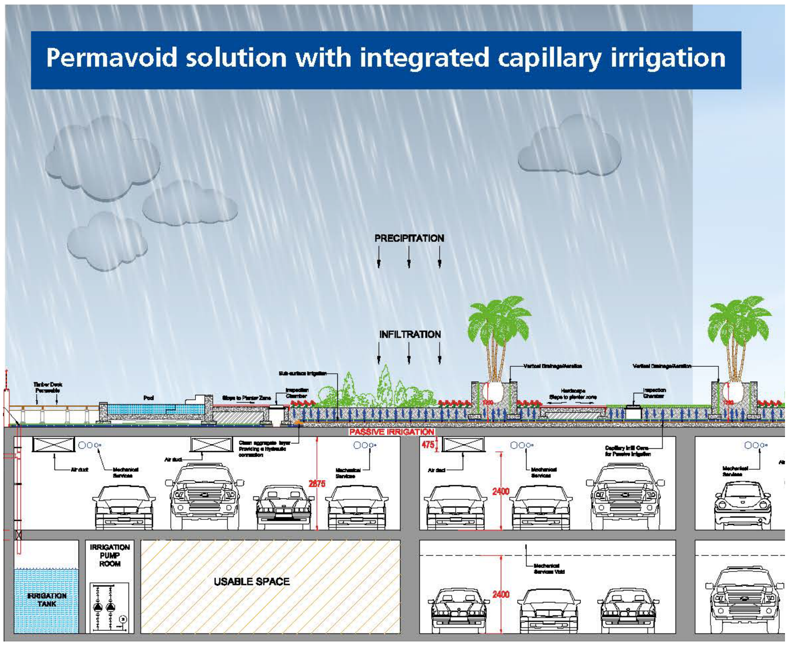



**Figure 1: Permavoid Solution with integrated capillary irrigation - Source: www.permavoid.co.uk**

Green Roofs can provide a variety of benefits in addition to water management. Extensive green roofs (sedum mats) have low biodiversity value, but Intensive Green Roofs and Biodiverse Roofs (sometimes called brown roofs) can provide habitats for a wide range of species. Biodiverse roofs in Canary Wharf have provided habitat for the endangered Black Redstart, whilst also creating urban cooling and reducing water runoff.

**Plate 5: Sky Gardens, Evesham Source: www.wikimediacommons.org Sky Gardens Ltd (CC BY-SA 4.0)**

The CIRIA SuDS Manual (2015) is the guidance followed by the industry in providing valuable and safe SuDS features within public spaces. The manual provides guidance on how to design attenuation features to limit the risk to the public, through incorporation of side slopes no steeper than 1:3 and safety 'benches' within attenuation features. CIRIA Guidance sets out how to use signage to educate the public about SuDS, rather than use signage to warn the public. With appropriate design there is no need for SuDS features to be fenced off or to include warning signs about 'deep water'.

## 3.2 Case Studies

### Ruskin Square, Croydon

Ruskin Square is part of a mixed-use redevelopment site adjacent to East Croydon Station[1]. The area is undergoing a programme of regeneration as part of the East Croydon Masterplan to create a new urban quarter with improved transport links, residential, retail and office space and an investment in public realm, built ahead of development.

The Ruskin Square and office development uses multiple SuDS features to attenuate and control flow including:

- Green Roof, providing biodiversity enhancement, water filtration and attenuation to manage 1 in 100 year storm events;
- Pervious Surfaces; permeable grit jointed granite paving that provides surface water attenuation.
- Geocellular Storage System; beneath Ruskin Square crates provide water attenuation prior to controlled release to the drainage network.
- Rain Gardens; surplus water runoff from the surrounding permeable paving is channelled into sunken planted rain gardens which contain a grove of semi mature pin oak trees.

[1] https://www.susdrain.org/case-studies/case_studies/ruskin_square_croydon_light_case_study.html


**Plate 6: Ruskin Square, July 2017 © J & L Gibbons / Sarah Blee (source: Susdrain website https://www.susdrain.org/case-studies/)**

## Rathbone Market, London

Owners English City Fund (ECF) entered into an agreement with landowner Newham Council to deliver a sustainable and mixed-use community at Rathbone Market, Barking Road, London[2]. The development includes 650 homes with shops and public landscaped amenity squares to produce a pleasant living environment. Facilitates include public walkways and ornamental ponds at podium level and an allotment for residents to develop at roof level.

Blue roofs were incorporated into the design to enable the roof area to be used for the attenuation of storm water, which is subsequently released to the drainage network at a controlled rate via restrictor chambers in the period following the storm. There were 6 separate roof areas;

- 2 with paved finishes for maintenance access only,
- 3 with biodiverse roof finishes to provide filtration and enhance ecology, and
- 1 providing an amenity area for a series of allotment gardens for the residents.

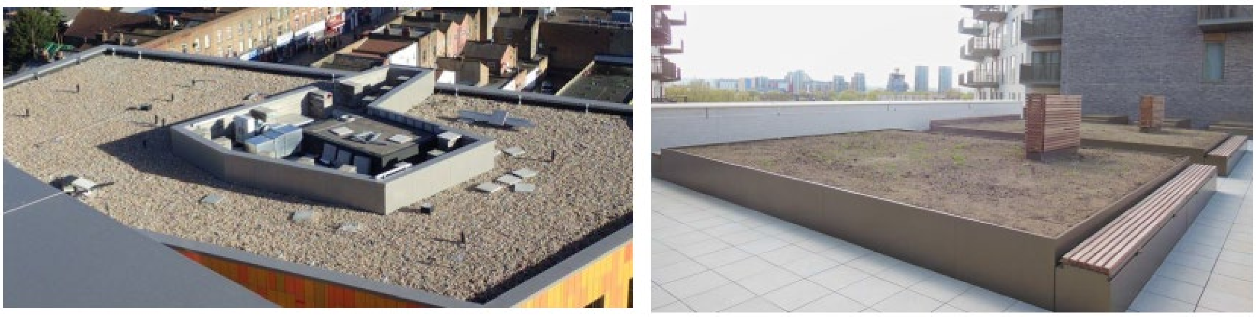


**Plate 7: Biodiverse roof and allotment gardens, Rathbone Market https://www.susdrain.org/case-studies/**

[2] https://www.susdrain.org/case-studies/case_studies/rathbone_market_london_light_case_study.html

## Sustainable Drainage Estates, London

Improvements were undertaken to three housing estates in London Borough of Hammersmith and Fulham with the support of Life+ European funding and Thames Water twenty4Twenty funding, both of which support the implementation of retrofit SuDS to meet a series of environmental goals[3].

The project has focussed on green infrastructure-based approaches to dealing with the effects of storm water and increasing communities' resilience to climate change whilst also delivering multiple other benefits including improvements in biodiversity, visual amenity, play provision, local food production and air quality. This project was innovative in demonstrating how known green infrastructure techniques, with their many benefits, can be retrofitted on a large scale into existing social housing estates.

Many small-scale interventions have been integrated within wider landscape improvements, including informal play features and revitalised community garden spaces incorporating ornamental and fruit trees and raised planters, with the aim of reducing pressure on the existing surface water drainage networks across the estates. A summary of these small-scale interventions are as follows:

Queen Caroline Estate:

- 142m$^2$ of biodiverse green roofs installed as source control on bins stores and pram sheds.
- Unused hard landscaping areas replaced with permeable landscape features including rain gardens, stony basins, permeable paving, composite decking and 'schotterrasen' (Austrian gravel lawns).
- Pebble or vegetated channels diverting run-off from downpipes to shallow basins/rain gardens and swales planted with wildflowers.
- Vertical rain garden irrigated by water collected from building roofs which is fed into raised planters containing climbing plants.

Richard Knight House:

- A 172m$^2$ extensive biodiverse green roof installed as source control.
- 66m$^2$ of extensive biodiverse green roofs installed on bin stores and pram sheds, draining directly to adjacent paving.
- Conversion of a 20m$^2$ strip of unused space into a combined rain garden and SuDS tree pit.
- Small linear rain garden planted with SuDS wildflower turf to correct an area prone to significant water pooling.

Cheesemans Terrace:

- Rain gardens with underlying infiltration trench taking water from paving and a section of the estate road.
- Rain gardens and shallow meadow-filled basins to take water diverted from adjacent car parking areas via simple dished channels.
- Aggregate-filled cellular permeable paving used for vehicular access to bin stores.
- Extensive green roofs added to pram sheds.
- Small meadow-filled basin in play area with associated informal play features.

The impact of the project is clear, with 4100m$^2$ of impermeable surface diverted from draining directly to the sewer, and approx. 4500m$^2$ of the estate land improved. During the initial monitoring period for the first 3,000m$^2$, 100% of the rainfall that fell within the catchment areas of the installed measures was diverted away from the sewer and managed in the landscape; and the green roofs absorbed an average of 84.15% of rainfall landing on them (a conservative estimate).

The SRI recently completed data analysis from the second year of monitoring (full results available online: http://roar.uel.ac.uk/7001/). Results from the second year of survey demonstrated that the retrofitted green measures continue to perform a range of valuable services to residents and the borough. Highlights of the monitoring included:

- The combined SuDS features diverting approximately 1,220,900 litres of rainwater away from the combined sewer system (June 2015 to 2016).
- An average of approximately 80% of rainfall being absorbed by the small-scale green roof.

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[3] https://www.susdrain.org/case-studies/case_studies/sustainable_drainage_estates_hammersmith_fulham.html

- A swale capturing, storing and infiltrating a 1 in 100 year simulated rain event even during the winter period when the ground would be expected to be more saturated.
- A total of 57 species of wildflower and grasses on a single green roof.
- An approximate 40% reduction in temperature on a green roof compared to a control roof on a hot summer day.

**Plate 8: Queen Caroline Schotterasen gravel garden adjacent to Adella House and permeable paving and composite deck**

**Plate 9: Sun Road, Cheeseman's Terrace, rain gardens**

**Plate 10: Richard Knight biodiverse extensive green roof**

## Alma Road Rain Gardens, London

Alma Road is situated in Ponders End, a deprived area in the London Borough of Enfield, part of the Brimsdown Ditch – Salmons Brook Catchment. This part of Enfield is generally low lying, as it forms part of the Lee Valley. The natural flow path to the nearby watercourse, Brimsdown Ditch, is obstructed by the adjacent railway line which exacerbates surface water flood risk.

As described in the case study available on the Susdrain website[4], the key objectives of the project were to:

- Reduce surface water flood risk;
- 'Normalise' SuDS and thereby encourage wider take-up;
- Improve the public realm;
- Make roads safer through the use of traffic calming measures;
- Inform rain garden design considerations and standards, so this could be replicated by Highway Engineers with ease across the borough.

A total of five rain gardens were built on a 200 m stretch of Alma Road. These were built into the footway and carriageway. Their shapes are such that the areas of rain garden are maximised on both the carriageway and footway without having a significant impact on pedestrian and vehicular traffic.

**Plate 11: Rain garden along Alma Road, Enfield**

## North West Cambridge – AECOM

North West Cambridge is an innovative community developed by the University of Cambridge. It provides housing for students and key workers and provides essential community facilities such as a local centre with a primary school, community centre, health centre, supermarket and shops.

AECOM developed a pioneering rainwater management strategy to capture and treat stormwater runoff from the site, using an integrated network of sustainable drainage systems (SuDS). Naturally filtered water is then stored and redistributed to homes to flush toilets and water gardens. This is the first stormwater recycling scheme in the UK and one of the largest in the world. Other key initiatives include an innovative waste collection system and a site-wide district heating network powered by a centralised low-carbon combined heat and power system. AECOM is also advising on how behaviour change can help residents to live more sustainably.

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[4] https://www.susdrain.org/case-studies/case_studies/alma_road_rain_gardens_london.html

**Plate 12: North West Cambridge Integrated SuDS feature. Source: AECOM (2019)**

**Plate 13: North West Cambridge Rain Garden. Source: AECOM (2019)**


**Plate 14: North West Cambridge Western Edge Park. Source: AECOM (2019)**

## Bernie Spain Gardens, London – Coin Street Community Builders

Bernie Spain Gardens are a local park in an international location. Created to provide attenuation for the surrounding residential development the gardens provide this through the shape of the central lawn area. The gardens provide multiple benefits in the form of a valuable green space in the heart of the South Bank, used by both residents, local people and tourists. The slopes of the attenuation basin provide a popular space for sitting in the sun and eating lunch, and for events and performances. The surrounding shrub and herbaceous planting provide a biodiverse site in a densely urban location and opportunities for community gardening. The adjacent residential flats benefit from a green view, whilst the easy access to outside space has additional health and wellbeing benefits.

**Plate 15: Bernie Spain Gardens – Source: www.flickr.com Robin Stott (CC BY-SA 2.0)**

**Plate 16: Bernie Spain Gardens – Source: Andrew Skudder www.flickr.com (CC BY-SA 2.0)**

# 4 Re-use Case Studies

## 4.1 Southbank Place – Lambeth

This development includes six greywater recycling systems (two in commercial towers and 4 in residential towers) with a total capacity of approximately 100 $m^3$ day of non-potable supply. The properties are interconnected allowing treated greywater to be shared as a non-potable water source between buildings. The system is supplemented by five combined rainwater attenuation and re-use tanks used for the cooling tower which also includes recycling of the discharged cooling water.


**Plate 17: Southbank Place**

## 4.2 10 Fenchurch Avenue – City of London

10 Fenchurch Avenue is a 15-storey high building and offers 420,000 sq ft of office space with additional retail use at the lower level. The building incorporates a publicly accessible rooftop garden with restaurant and water features.

**Plate 18: 10 Fenchurch Avenue**

The unique design includes an “integrated non-potable water management” approach where flood management aspects are integrated with water efficiency measures.  A combined rainwater harvesting, attenuation and greywater recycling system was installed at basement level and a further rainwater harvesting combined attenuation system on level 14.

To further advance the efficient storage of water, a cloud-based weather control system from Aquality was incorporated to manage the rainwater volumes. Aqua Storm control is an innovative addition to rainwater harvesting and it enables the systems to switch their functionality between attenuation storage and water usage. This radically reduces the need for high storage volumes, compared to conventional systems, as the one system does both jobs.


**Plate 19: Aqua storm control system, 10 Fenchurch Avenue**

## 4.3 Principal Place, Commercial, London

Principle Place is a commercial development in Shoreditch which is served by a combined grey and rainwater harvesting system[5]. It uses Aquaco's Vellamo™ Smart Attenuation and control system which uses a large attenuation chamber as the main system storage tank. The system monitors live Met Office data and in the event of an imminent storm event, the tank is automatically drained to provide the required attenuation volume to prevent flooding, reducing overall plant space and allowing for larger overall storage capacities.

**Plate 20: Principle Place, Shoreditch**

## 4.4 62 Buckingham Gate, London

Adjacent to Victoria Railway station the development at 62 Buckingham Gate, which comprises office, retail and leisure uses, includes both a rainwater harvesting system and a rainwater attenuation system, supplied by Aquaco[6].

The rainwater harvesting system has a capacity of 20,000 litres, whilst the rainwater attenuation system, which incorporates a flow control mechanism designed to limit the discharge rate to mains drainage, has an additional storage capacity of 150,000 litres. Both systems were supplied and commissioned in 2013.

The rainwater harvesting systems collect rainwater from roofs and/or hard standings to re-use for toilet flushing, laundry and irrigation, thereby reducing demand for mains water.

**Plate 21: 62 Buckingham Gate, London**

[5] https://www.aquaco.co.uk/case-study/principal-place/
[6] https://www.aquaco.co.uk/case-study/buckingham-gate-rainwater-harvesting/