DG1	MARCH 2019

POLYPIPE

Inspiring Green Urbanisation

THE DESIGN GUIDE

Polypipe

Evolving to meet the challenges of climate change

To some, it may seem a little out of kilter for a company called 'Polypipe' to produce a Guide all about Green Urbanisation. But it's not as left field as one might think. Throughout our history, we have been at the forefront of surface water drainage innovation – as this Guide serves to further demonstrate.

We're continually evolving our systems and products to challenge the events brought on by an ever-changing climate, working to reduce the impact it has on our towns, cities and urban areas – as well as helping to make the people who live within these areas have a more comfortable and environmentally secure future.

Traditional piped drainage systems still have an important role to play in ensuring the resilience of our towns and cities, but that said, they are now only part of the solution. Increasingly Planners, Developers, Designers and Installers are looking to employ alternative drainage strategies. Those based on nature, which control and manage rainwater where it falls, (at source), but also protect and enhance the urban environment. Modern drainage solutions now need to provide more than just conveyance, they have to be smart, delivering multifunctional benefits whilst making space for water to turn challenges into solutions.

The development of systems from Polypipe provide innovative drainage solutions that not only intercept and manage stormwater; helping to prevent flooding, but that are also able to reuse it. Capture and clean it as part of a permeable pavement system. Use it to protect and allow inner-city trees to thrive as part of a planted drainage system. Repurpose it to naturally irrigate green surfaces from below; thus saving on potable water and easing the strain on our sewer systems. And managing it efficiently and effectively with vegetation to help create evaporative cooling by evapotranspiration from plants and soils – helping to cool inner cities, offset the Urban Heat Island effect and ultimately, help to create places where people want to be and where biodiversity can thrive.

These are truly modern times, and we need truly modern water management solutions to keep up.

Jason Shingleton
Marketing and Development Director at Polypipe

Making the difference with intelligent water management

Recent history has demonstrated the critical importance of effective water management in securing a resilient future. At Polypipe, we are developing integrated solutions with the capability to inspire a re-imagination of urban landscapes. By harnessing the benefits of emerging technologies and materials breakthroughs we are pushing the performance envelope, creating opportunities for designers and developers to bring sustainable ecosystems into the heart of our built environment.

We've been successfully designing and providing engineered SuDS solutions since 2004, but, whilst still effective, we need products and systems that deliver more. The increase in urbanisation and the impacts of climate change, therefore, have pushed our innovation skills further. To develop new technology. To engineer enhanced systems that make space for water. And to create and sustain Green Urbanisation.

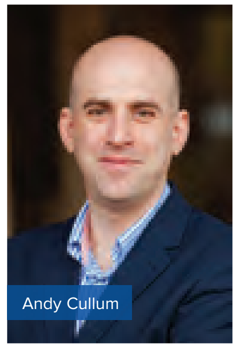
Polypipe Green Infrastructure systems have been developed as part of our water management solutions offering to complement our existing engineered SuDS solutions, enabling you to design drainage systems through planting; creating biophilic design. This helps to reconnect human life and wellbeing through nature whilst, at the same time, constituting an effective and efficient drainage system.

Polypipe provides solutions that consist of products that complement and support natural vegetation; trees, shrubs and grasses, and self-manage water efficiently and effectively using Permavoid units with Capillary Cones to provide the plants with water and nutrients. This creates natural irrigation without using pumps, hoses, or energy; just like nature – whilst traditional engineered solutions can enhance the biophilic design to deliver successful Green Urbanisation, and water management and drainage solutions.

The benefits can also include helping to control surface water run-off which can earn valuable BREEAM points, helping towards a faster, more successful planning approval.

It's through training, unequalled expertise, knowledge, insight, research and working with our customers that ensures we can meet future challenges and help the construction industry achieve its goals, that are inspired by Green Urbanisation, in an ever-changing climate and construction environment.

With an accomplished career spanning over 30 years collectively, Andy Cullum, Sales Director at Polypipe Civils and Sean Robinson, Business Development Director – Specification, are at the leading edge of research and development. A Civil Engineer himself, Andy leads his team with a customer-focused approach and understands precisely the needs of the industry, to be able to complete schemes effectively, efficiently and to manage water intelligently. Working alongside Andy, Sean, with his technical know-how supported by a degree in science, has a tenacity to find alternative solutions to help with the challenges the industry faces. Whilst helping design products and systems that allow schemes to include Blue-Green Infrastructure and biophilic design.



Andy Cullum

Sean Robinson

Within the Guide, we've drawn attention to past and current challenges that highlight why intelligent water management solutions are more important than ever to ensure a more resilient future for our cities and urban spaces. We've also provided an insight to our water management projects and how we can help design systems for multifunctional applications using products to enhance performance whilst meeting all-important industry regulations.

The foresight and experience to make the difference

Since 2004 we have been successfully manufacturing engineered Sustainable Drainage Systems (SuDS) to support the construction industry at every stage of its growth – and helping it to move forward with solutions that demonstrate exceptional performance. With continuous research and development, we have become the market leader in water management solutions – designing drainage systems that successfully meet the requirements of today's construction markets.

Historically – and naturally – we've been a company of innovators, problem solvers and solution providers, and so appreciate we will always need systems that deliver more. The increase in urban construction has pushed our innovation skills further to develop new technology. To engineer enhanced systems that make space for water. And develop systems that create and sustain important green spaces.

Drawing from what we know already, we've been able to implement water management know-how into creating Green Urbanisation. It's an area where we can add real value – not simply from a financial perspective but, more importantly, from a health and wellbeing point of view.

We have the capability and scalability to deliver. With our leading-edge design expertise, innovative technology, detailed understanding within our sectors and our own award-winning delivery fleet, we're able to provide the support and service you need to bring whole life value to your projects. And we can provide the right systems – from the biggest range – that are engineered to perform.

With the cause for resilient cities a world-wide initiative, intelligent water management solutions – whether engineered SuDS or Green Infrastructure applications – are more important than ever to ensure a more sustainable future for our cities and urban spaces.

A multifunctional approach to Green Urbanisation

Introducing effective SuDS solutions that incorporate Green Urbanisation, can deliver multifunctional benefits such as rooftop amenity and the cooling of urban environments. Indeed, Urban Planners are discovering innovative ways to adopt a multifunctional approach to Green Urbanisation and our aspiration is to work with them to develop those innovations – particularly in new development design, where there's an opportunity to maximise multifunctional space.

Get the best from using the Guide

The Polypipe Design Guide is to be the industry-standard go-to piece to understand the challenges cities, urban areas and indeed our construction industry face as a result of climate change and the increase in urbanisation. It details how we can embrace these challenges and overcome them by making space for water and introducing Blue-Green Urbanisation.

We've divided the Guide into four sections – helping you through a succinct and logical journey, providing you with the information you need to deliver projects that are able to meet and perform beyond your objectives.

Section 1.
Why Green Urbanisation?

The section introduces the challenges that the UK and the rest of the world face due to climate change, how it's affected the way in which we think about managing water – and the detrimental effects it can bestow if making space for water isn't considered in the future planning of urban projects. You'll find useful case studies and information demonstrating how we're turning the situation around through managing water more effectively and including Green Infrastructure.

Section 2.
Why Polypipe?

Throughout this section, we'll demonstrate that considered design, including green space, can be achieved both cost effectively and provide multifunctional benefits using systems specifically designed to make space for rainwater – to capture and store it at source, treat it and reuse it. And, through constant innovation and focused research and development, at Polypipe, we're uniquely positioned to offer solutions that help deal with the pressures placed on urban environments and natural resources.

Section 3.
The Technical Solution

The Technical section provides a comprehensive overview of all the component parts that help manage water to its fullest potential. Detailed drawings and 'how-to' examples demonstrate how each one, either as a stand-alone solution or as part of a SuDS, can bring multifunctional benefits to a project. And each section will provide build techniques to help you deliver a system with the least amount of effort; that can not only help towards a greener, more sustainable environment, but could also help towards human wellbeing, health and general happiness.

Section 4.
Proprietary Products

Whilst the Technical section delivers the water management capabilities of the applications featured, the Proprietary section demonstrates how Polypipe's additional products and systems can enhance those applications, allowing for more accomplished results that go beyond the normal recommendations, to ensure a system and scheme that's prepared for the future.

Pick and Choose

The Guide has been designed so that information can be accessed easily. Chapters and sections, therefore, have been tabbed along the edge for instant reference, internal section headers are visibly numbered and titled; with each one enhanced with a significant image. Simply 'thumb' to the section or chapter that fits your criteria – but we recommend a cover-to-cover read first to fully understand why you should design your project to include Green Infrastructure.

Inspiring change through Green Urbanisation

Through a skilled understanding of engineered surface drainage solutions and the importance of intelligent water management, we are able to offer advice and support to inspire you to include making space for water and Blue-Green Urbanisation in your projects.

Together we can make a difference providing multifunctional benefits that will help towards a resilient future, better environments in which to live and enjoy and places where wildlife can flourish. Throughout the Guide, you will notice the following icons to help you identify projects, products and systems that deliver these benefits.

MAKING SPACE FOR WATER

With flooding ever more prevalent within our urban areas, we've developed and engineered systems to help make space for water – from Roof to River. Our engineered SuDS work independently to manage rainwater at source but can also complement soft SuDS such as ponds and swales to enhance their water management capabilities.

SURFACE WATER MANAGEMENT

We design systems that include areas where water can be intercepted or captured at source and stored. Not simply drainage systems for conveyance, but those that can reuse the stored water to irrigate green spaces above or release it at a controlled rate.

WATER QUALITY

Our range of water treatment solutions are designed to filter and treat rainwater at source by removing harmful road surface pollutants, preparing the water before it enters our geocellular storage units ready for reuse.

PLACEMAKING

Our engineered water management solutions combined with soft SuDS techniques can create green spaces for people to use; playgrounds for children, community gardens, green corridors that include cycle paths and walkways, and even sports pitches that are self-sustainable.

AMENITY

To enjoy green spaces within an urban environment, we've systems to create inviting and enjoyable places for people; Blue-Green roofs and podium decks (at ground and roof levels), roof bars, meeting areas for lunchtime outdoors, children's play areas and sustainable roof gardens.

URBAN FARMING

Our land drainage systems are easy to install and can open up opportunities for otherwise unusable land – ultimately improving crop yields as well as the fabric of the community.

HEALTH AND WELLBEING

Our engineered geocellular products are designed to collect and store water below podium decks, which can then be reused for the irrigation of trees and vegetation; creating green spaces, calming areas that offer relaxation and a sense of community whilst promoting wellbeing and positive health benefits.

BIODIVERSITY

Our systems can reuse rainwater to irrigate plants, trees and grass above, introduce wetlands for wildlife within new developments, and even mimic natural swales to attract birds and insects back into our cities.

CLIMATE COOLING

Our sustainability credentials are as important to us as the products we provide, building-in carbon and water-sustainable solutions to promote greenery, irrigation for large canopy trees as part of a planted drainage system, evaporative cooling and a natural water cycle. All resulting in helping reduce Urban Heat Island effect.

ASSET CREATION

Designing Green Urbanisation with water management solutions enhances the environment and encourages more investment which can create more amenity and better places to be. Restaurants and bars can be built on rooftops which were once unusable hard landscapes and generate revenue by cleverly making space for water.

Contents

Everything you need to know, under one 'Blue-Green' roof

In a time when environmental debate continues on an ever-vigilant course, it seems almost unnecessary to bring yet more information to the party – especially within the construction industry where the subject has been covered more times than a well-thumbed book. However, there's more to be done, more to learn and more we can do as an industry to ensure our cities become more resilient to climate change and the adverse effects it brings – and support them for now and in the future.

1

This Guide sets out to reinforce the importance of designing Blue-Green Urbanisation into future and retrofit schemes and how it can only be achieved through good water management.

This is a guide that highlights the depletion of our green environments, it covers how high-density concrete landscapes affect climate change which leads to flooding. It's a guide for everyone, not just for our industry. This is to be the go-to, single-place reference guide for planners, landscape architects, architects and contractors. Everyone is talking about biodiversity, amenity, potable water, rainwater reuse – and they are 'rumblings' that aren't confined to the commercial sector – but within the consumer space, too.

There's a distinct air of complacency surrounding Green Urbanisation, consequently, directives, such as National Capital Accounting and the Balanced Scorecard Approach, have 'tools' that the construction industry can refer to and implement, ensuring Blue-Green Urbanisation is included in procurement processes whilst achieving value for money – and non-financial benefits for all – for each project. Understanding such directives will help to explode the myth that planning with Blue-Green Urbanisation is difficult.

Ultimately, the Guide aims to highlight the problems cities face as more and more building prevails. It will show how 'we' can all address these issues and provide solutions through clever water management – to inject green back into our cities whilst making space for water, create a feeling of wellbeing and calm, healthier lifestyles and help towards a more resilient future.

To understand is to succeed

Green Urbanisation (GU) isn't new. But as we take steps to ensure our cities are sustainable and more resilient, it's something that needs deeper understanding. In simple terms, there's no green without blue.

GU, and also Blue-Green Urbanisation (BGU), isn't simply about adding greenery to urban developments – it's about incorporating water management solutions into project designs to deliver a multifunctional outcome that helps reduce the impacts of climate change while improving the health and wellbeing of the people who live within our cities.

Flood mitigation, rainwater storage, reusable resources and innovative ways to encourage trees, vegetation and biodiversity should all be a part of your project design. And involving us at the early stages will guarantee more considered results going forward; helping with Balanced Scorecard criteria, for example, to ensure swift approval through a clear understanding of the procurement process.

There's no denying it – developers face more challenges than ever. Population growth within cities is showing no signs of slowing down and climate change has increased severe weather flooding, Urban Heat Island effect (UHI) and pollution.

However, Urban Planners all over the world are discovering innovative ways to adopt a multifunctional approach to GU thereby helping to transform cities and improve their resilience.

A natural water cycle, with water management solutions act to propagate, irrigate, cool and promote evaporative cooling. And introduced effectively, SuDS create a water management solution that is self-perpetuating whilst helping to reduce stormwater run-off into sewers and waterways.

The economic benefits of BGU can't be ignored either. Pleasant green urban spaces attract inward investors as well as biodiversity and improve property and land values. However, a sense of wellbeing and community can be achieved with National Capital Accounting; the directive that helps councils put a value on green space. These areas create important amenity such as green link cycle paths, green corridors to connect one area to another – sustainable green spaces for people to use, which helps towards community cohesion, prosperity and comfort.

In fact, there are many reasons why we should continue to design and develop our cities using BGU– climate change, Urban Heat Island effect (UHI), and air pollution providing reasons enough. In the UK, Polypipe has a clear understanding of the issues facing our cities. We've already developed and engineered products and systems to provide space for water for successful BGU projects in London and beyond.

Taking the initiative with Green Urbanisation and Water Management Solutions

As we move further into the 21st century, our cities face accumulated stresses and sudden-shock risks. The development of land, trying to accommodate more and more people into our cities and ignoring climate change could result in greater physical, social and economic challenges.

Creating BGU will become increasingly vital for ensuring our cities are prepared for growing populations, and becoming resilient in the face of disruptive events – big and small.

But resilience isn't born out of traditional risk assessments relating to specific events. Today, a resilient city is one that incorporates a system that helps bridge the gap between disaster risk reduction and climate change adaptation. It has the ability to readjust to mitigate unpredictable threats – helping to preserve the integrity of physical, social and economic systems.

We learn through research, but also by experience. The increase in hard landscaping distorts the natural water cycle by reducing green space, further exacerbating the risk of flooding incidents. In the past, cities – and rural areas alike – have been designed to accommodate businesses, leisure facilities, car parks and human living at the expense of green space, biodiversity and clean air. As city populations continue to grow, the quality of our urban environments will continue to suffer.

However, incorporating BGU into new construction developments and retrofit projects will provide multifunctional benefits which could alleviate the possible effects of climate change and population growth. In doing so, we'll see biodiversity return to cities and the impact of severe weather better managed, allowing cities to recover faster in flood events.

With water management solutions key to the development of GU, we are well positioned to help the industry from the early stages of design and planning to make space for water and contributing to the resilience of our cities and urban spaces.

"Could it not be possible to build cities more in harmony with nature? ... It is surely our responsibility to do everything in our power to create a world that provides a home, not just for us, but for all life on earth."

Sir David Attenborough, Planet Earth II, 2016

The tipping point

Over time, the dramatic rise in population combined with an increase in energy consumption, high carbon emissions and an absence of green open spaces has paved the way for serious problems in cities all over the world – such as a distorted water cycle and the depletion of important biodiversity.

By 2050, the human population will have reached 9 billion; of this, 75% are expected to be living in cities and it isn't showing any signs of slowing down.[1] London alone is set to rise from 8.63 million (2016) to more than 11 million by 2036[2], with global urban population predicted to be more than double that of the rural population right now.

As cities have developed quickly to accommodate more and more people, vegetation has been lost in favour of hard landscaping and buildings. Sir David Attenborough states that, every ten years the world loses an area the size of Britain under a layer of concrete.[3] It's no surprise then that shade from trees has diminished along with moisture retention to keep these areas cool. As well as the destruction of biodiversity, this has led to a surge in energy consumption, air pollution, and severe flooding.

Population growth in London

Mendora Road

Whilst we cannot undo the mistakes of the past, we can right our wrongs by turning to a greener, more balanced approach to planning and developing – not only for new buildings and structures but by retrofitting existing ones too. By integrating a more intelligent way to manage water at the beginning of the design process, multifunctional benefits, such as placemaking, amenity and water reuse for example, can be built into projects. The result will not only deliver significant health benefits, but go a long way to enhancing cities with substantial social, environmental and economic benefits.[6]

1. Cities Alive – Rethinking Green Infrastructure, Arup, pg 25, 2014. 2. World Population Review, 2017 (www.worldpopulationreview.com).
3. Planet Earth II, BBC, 2016. 6. Public Health and Landscape: Creating Healthy Places, Landscape Institute Position Statement, by the Landscape Institute UK, 2013.
(For Greenlink Motherwell - Forestry Commission Scotland).

Distorted water cycle

The cycle of water in nature effectively uses evaporation, condensation, transpiration and precipitation to work. It sustains a healthy atmosphere, promoting strong vegetation and a predictable climate.

However, introducing hard surfaces and inadequate rainwater systems disrupts the natural cycle, leading to an increased risk of flooding. Rainwater run-off from roofs, for example, drains directly into wastewater sewers, increasing flood risk within urban and downstream suburban environments. At the same time, a lack of vegetation and transpiration distorts the cycle further.

"Between 2003–2013, natural hazards and disasters in developing countries affected more than 1.9 billion people, and caused more than $494bn in damages. Economic losses from natural disasters have tripled over the past decade, and continue to rise."

Clár Ní Chonghaile. Editor, Global development desk, The Guardian, March 2015.

Urban Heat Island (UHI) effect

UHI in particular is reaching critical levels in developed cities worldwide. Buildings, streets and grey infrastructure, can create confined spaces, trapping heat and pollution.

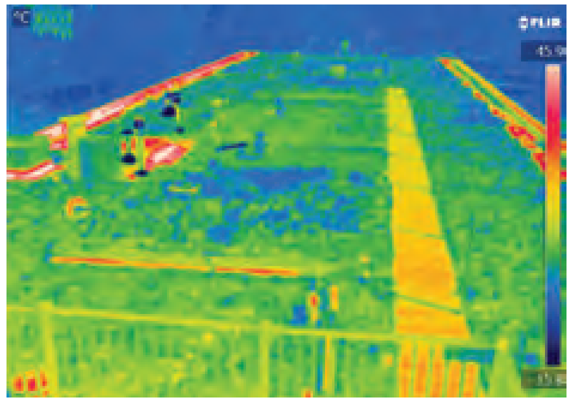
Combined with the lack of vegetation, the heat is simply absorbed into the concrete without respite from trees and other plants to clean and cool the air. Of course, we accept urbanisation, but with temperatures potentially reaching up to 12°C higher than rural areas at night as the concrete releases the 'stored' heat[4], it's important we make space for water to help redress the balance. Geocellular units can be installed below ground or on roofs to store, reuse and attenuate rainwater. Captured at source, this water can be used to create areas of vegetation, amenity and tree planting above the units, helping to cool the air, reduce pollution and create a more comfortable place in the process.

A developed country city of 1 million people can experience temperatures 1°C to 3°C higher than its surrounding areas, and up to 12°C more at night when UHI effects are strongest.[4]

Increased energy consumption

With the increase in population, global energy consumption is a growing concern.

Not least in our cities where compact architecture and a lack of large trees and green spaces make for higher temperatures and the need for air conditioning. In a time where cities are responsible for three-quarters of the world's energy consumption and 80% of its greenhouse gases[5], it's time to become more vigilant – not only in the way we plan and develop changes within our cities, but in how we generate and consume energy.

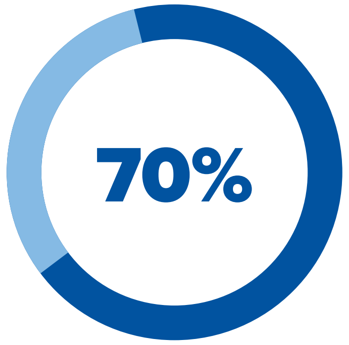


The carbon challenge

Cities demand high energy consumption, produce more greenhouse gases and leave an ever-increasing carbon footprint.

Traditional infrastructure, lifestyle choices and poor insulation contribute to carbon emissions each year. Making homes more comfortable and work environments more in-line with modern-day expectations contribute to our cities' carbon footprints. But with the increase in population comes an increase in other activities like cement production, deforestation and the burning of fossil fuels.

Whilst much smaller than natural emissions, human-based carbon emissions have affected and altered the natural balance that existed for many thousands of years before human involvement.[9] This is because natural green environments – areas of vegetation that absorb more CO_2 than they release – removed around the same quantity of carbon dioxide from the atmosphere than was produced by natural sources. By adding extra carbon dioxide and removing natural green infrastructure has resulted in an upward trend in carbon emissions. Designing with GU/BGU and making space for water, however, will re-introduce vital natural environments to help mitigate harmful emissions, whilst attracting vital biodiversity and nature into our cities.



"Global energy demand is expected to double or even triple by 2050 by which time 70% of the world's population will be living in cities."

Arup, Five minute guide, Energy in Cities.

4. Global Report on Human Settlements, Cities and Climate Change, United Nations, pg 69, 2011. 5. Five minute guide, Energy in Cities, Arup.
9. Main sources of carbon dioxide emissions (www.whatsyourimpact.org).

Potable water and sewers under pressure

With increasing urbanisation and the complacency surrounding water usage, potable water and wastewater sewers are feeling the strain. Population growth is on the rise[1], especially in our cities, so naturally, everyday life of washing clothes, cleaning vehicles and watering gardens continues and increases exponentially.

With wastewater sewers and drains in some of our cities being out-dated, they're unlikely to cope in a severe weather event – especially with the added volumes due to the rise in urbanisation. And it's a problem that is further exacerbated with the misuse of potable water.

Arundel Gardens

It's more important than ever before, to consider how water can be reused. The run-off can be collected from roofs and other impermeable areas, stored, treated (where required) and then used as a supply of water for non-potable applications. And systems, such as underground and podium level units, can intercept rainwater run-off at source and is then able to control the amount of water stored or attenuated.

Depending on the proposed use of the intercepted water, the collected water can generally be used for a range of non-potable purposes, such as internal utilities, washing machines (which may require adaptation) and for external uses such as car washing and irrigation. Taking positive steps to intercept our rainwater will help to conserve potable water while reducing the strain on sewer systems.

Loss of biodiversity

With the increase in population and expansive growth of cities around the world, ecologically sensitive areas are slowly being eroded or disappearing.

The constant need for space to build upon has led to the destruction of natural habitats and, in doing so, is affecting the fabric of biodiversity within our own environments. Now, more than ever, it's vital to design future developments with nature-based solutions as a priority. It will not only help to reduce the impact of a changing climate, but will reintroduce habitats for wildlife and restore balance and harmony in our cities and urban spaces.

Green spaces naturally attract biodiversity, the species of vegetation will also have a difference to how diverse wildlife will be. A simple addition of Permavoid below podium decks or permeable pavements can create self-sustaining Green Urbanisation above bringing with it valuable and interesting new habitats for animals and insects.

Loss of green space

Water supply, natural cooling and biodiversity – can all be disrupted or lost by the absence of valuable green spaces in the built urban environment. But the loss of parks, sports pitches, playgrounds and other amenities can have an adverse effect on human wellbeing.

People prefer living in green neighbourhoods. Moreover, research shows we recover faster from illness, reducing the cost of healthcare.[36] Also, limited access to open green spaces, trees and nature in general is associated with a lower life expectancy.[6] Simply having a view of a tree through a window, for example, is enough to lower stress and blood pressure.[7]

With that in mind, it's hard to imagine that green space within urban environments in the UK was undervalued with funding for green spaces at one time reported to be reduced or cut completely.[8] But we've come a long way in a short time and National Capital Accounting has helped bring a more progressive and sustainable approach to urban development – placing value on our green spaces, helping to create community amenity, places where people can feel comfortable, safe and content – areas that local authorities see as an asset for everyone. First and foremost.

1. Cities Alive – Rethinking Green Infrastructure, Arup, pg 25, 2014. 6. Public Health and Landscape: Creating Healthy Places, Landscape Institute Position Statement, by the Landscape Institute UK, 2013. (For Greenlink Motherwell - Forestry Commission Scotland). 7. Greenspace design for health and well-being – practice guide, NHS Forest, Forestry Commission, 2012. 8. Green spaces under threat from planning system and funding crisis, The Telegraph, 2014. 36. (http://www.warwickshirewildlifetrust.org.uk)

Turning cities around

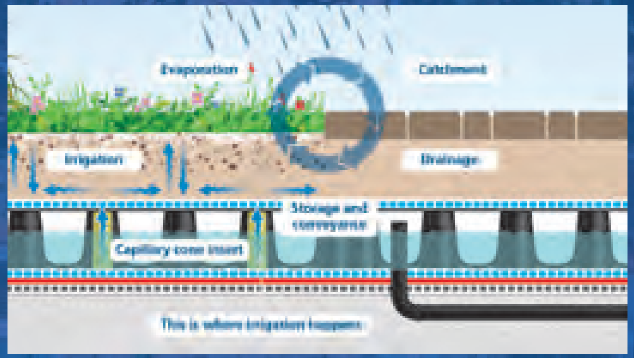
Already, there's positive movement towards making cities in the UK, and indeed around the world, more resilient. We're seeing structures like green walls and Blue-Green roofs. Natural swales along our roadsides intercept water run-off, whilst permeable pavements allow water to pass through to the soil below. Trees can be incorporated on podium deck designs to sit above underground car parks. Rainwater is intercepted at roof or ground level for re-use on green spaces.

Melina Road

Green Urbanisation, Green roofs or Blue-Green roofs capture, convey and manage water to turn it into a valuable resource. After all, why have a system that drains water when you can have one that manages it?

As we know, installing SuDS that can store rainwater, either for reuse above or below ground, can help reduce the strain on sewers, create amenity and attract biodiversity. But we can go further. Through innovative thinking and constant research and development, we can deliver products and systems to help designers achieve so much more.

Polypipe Capillary Cone inserts for example, have been developed to integrate with our geocellular units to control the amount of water and nutrition needed to irrigate trees and vegetation above. The system works via a wicking process using Capillary Cones and specialist geotextile, providing water when needed by the vegetation or retracts water when there is too much – constantly optimising the soil moisture content. The amount of water required can be calculated to the exact requirement if necessary – in addition, as the vegetation is irrigated from beneath, evaporative losses are reduced increasing the efficiency of the system. It's this kind of thinking that allows Green Infrastructure to flourish.

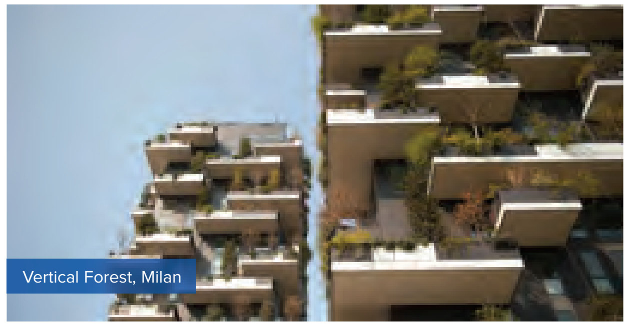


Water storage can also help limit the effects of heatwaves on vegetation by feeding from beneath. This is an effective solution which mimics natural evaporation, promotes CO_2 absorption and cools the air. Together, they work towards restoring a natural water cycle.[35]

Planting large-canopy trees next to south facing buildings can provide enough shade to significantly reduce Urban Heat Island effect. Using greenery to cool a building can also conserve energy, reduce the need for air conditioning and cut carbon emissions in the process.[10]

We can promote healthier living[11] and restore the balance between human living and wildlife habitats. All whilst having the potential to recoup – in part – the project expenditure. Through BGU, we can turn concrete jungles into green mixed-amenity spaces to live, work and socialise.

10. Joining the Dots. A framework for sustainable, resilient and cost-efficient Blue-Green cities. 2017. 11. Cities Alive – Rethinking Green Infrastructure, Arup, pg 11, 2014.
35. (www.recyclingexpert.co.uk/understanding-natural-water-cycle)



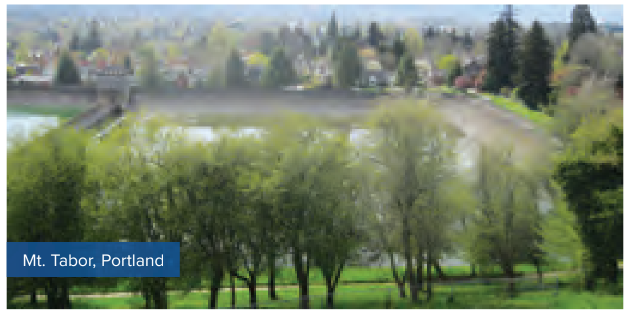
Vertical Forest, Milan

Milan's Vertical Forest; blueprint for The Green City Project, Nanjing, China

Architect Stefano Boeri, who previously designed the Vertical Forest in Milan, complete with 23 species of trees and 2,500 cascading shrubs, is the brainchild Architect of the now, world-famous Green City project.

Designed to combat China's remarkably high levels of air pollution, the two tree-clad skyscrapers in the province of Jiangsu, are estimated to produce around 60kg of oxygen every day and absorb 25 tonnes of carbon dioxide each year.[17]

Just as remarkable, the towers of foliage in Milan, set within a dense urban environment, are equivalent to 7,000m² of forest.[18] Both projects, with vast vegetation, also absorb impurities and dust produced by traffic. In short, people can breathe cleaner air whilst enjoying buildings that change colour with the seasons.



Mt. Tabor, Portland

(© Another Believer 2012)

Mt. Tabor, Portland, Oregon, USA

The nature-based SuDS solutions installed in this project are designed to clean surface water run-off by cleverly using the natural terraces of the mountain to process stormwater.

The entire space is surrounded with scenic walkways and promenades for recreational use. The system has proven to effectively cope with storm events, cutting overflows into rivers by 35%.[12] The project demonstrates how natural drainage can be effectively integrated with urban landscapes, adding economic, social, environmental and aesthetic value to cities.

Gardens by the Bay, Singapore

Gardens by the Bay, Singapore

The SuDS and BGU vision has been realised on a large scale at this 250-acre nature park developed on reclaimed land.

Designed by British firms, Grant Associates and Gustafson Porter, the development uses cutting-edge SuDS to control temperatures in its expansive conservatories. Five water inlets have been designed to match wind direction and channel wind and water from the shoreline into the gardens, sending chilled water through pipes within the subfloor, cooling the ground and allowing air to settle at ground level within the occupied zones.[15]

Impressive, too, is the Marina Bay Hotel that forms part of the Park landscape. Spanning across the top of its three already imposing towers, is the Sky Park – a structure so immense that it accommodates the world's largest rooftop infinity pool complemented by lush, green vegetation and palm trees. But it's at ground level where the magic happens. On-site is the lotus flower-shaped ArtScience Museum within the hotel grounds. Its roof has been designed to capture 500m³ of rainwater, which cascades into a filtration pool below and recycled to flush toilets systems.[16]

The Green Alley Scheme, Chicago, USA

This was a city where more than 3,500 acres of impermeable surfaces prevented rain water from soaking into the ground.

Rather than retrofitting traditional storm drains – a prohibitively costly exercise – replacement permeable pavements were installed. The high-albedo surface not only reflects sunlight to reduce UHI effects, but also allows stormwater to filter through to 'catch basins' that funnel the water into the ground. Between 2006 and 2010, more than 100 alleys had been upgraded to Green Alley status. When complete, the 1,900 miles of public alleyways in Chicago will be able to absorb up to 80% of rainwater falling on them, filtering water back into the earth – reducing flooding as well as the financial strain on the taxpayer.[13]

Colourfield, New Delhi, India

Colourfield, New Delhi, India

Whilst we can't improve the performance of athletes, at Polypipe, we can certainly improve the performance of the surfaces they play on and the venues that surround those surfaces.

One such scheme is Colourfield; a durable, multi-functional and sustainable mini sports arena in New Delhi, India.

Based on India's ambition of hosting future big sporting events, Colourfield came into play to demonstrate – at a grassroots level – innovative sports infrastructure. The installation of Permavoid allows the pitch to capture rainwater where it falls – at source – and filtrate it through the soil and into the cells beneath. With a unique jointing mechanism of clever clips called Permaties, the units form a rigid interlocking raft which is extremely strong and supports the overall structural load.

The real benefit lies in the Capillary Cones. Unique to the Permavoid system, these vertical fibre cylinders draw water upwards in a wicking action to irrigate the pitch, resulting in immense savings in potable water usage. Indeed, a pitch of 8,000m² has the capacity to store approximately 680,000 litres of water, helping to maintain the integrity of the pitch surface during dry weather spells whilst cooling the surrounding area with the evaporative cooling properties afforded by healthy vegetation.

Polypipe's Permavoid system was designed and tested as an alternative to traditional aggregate methods and improved reliability, stability and storage volumes.

Orlysquare, Amsterdam

Orlysquare Amsterdam

Orlysquare Roofpark in Amsterdam is testament to the human need for green space.

With the once-mono-functional landscape in danger of becoming a barren wasteland, the area (and the location of Amsterdam's Sloterdijk Train station), has been transformed into a multi-functional green oasis providing recreation, amenity, and a sense of wellbeing. But the project's trump card is how it was achieved. The site sits aloft mainline tracks for the incoming trains to the station, essentially making it a rooftop project. So the challenge was how to take the abandoned sprawl of concrete that marked its past function as a bus station and reimagine it to include water management solutions for a multi-functional outcome.

The design involved excavating the area to provide gardens, walkways, space for over 1000 bicycle bays, eating establishments and cycle ways. For the project to be a success, Polypipe's Permavoid units and geotextile were used. Favoured for its flexibility and ability to store and reuse water, the system was perfect for passive irrigation for the new low-level planting and mid-sized established trees, whilst also serving amenity within the immediate vicinity with treated water for utility services and cleaning. And to help with flooding and pooling, the units capture rainwater run-off at source, then store and reuse it throughout the park. And with the addition of Capillary Cones within the geocellular units, the water is stored until the plants on the site require it – which also helps with evaporative cooling through evapotranspiration.

Now a sustainable and green public space, the area, with its injection of vitality, is encouraging people – both local and tourist – to visit and linger; utilising short-stay hotel facilities, cafés and the park itself simply just to sit and relax. The strategic planting offers aesthetics and beauty whilst attracting new and much-needed biodiversity. And hotels in the area have increased rooms to accommodate more visitors – in stark contrast to the area's history of failing businesses and transient traffic. The Orlysquare is now a major hub, where people from the city, harbour, business district and tourism come together to meet, enjoy events and work.[33]

12. Mt Tabor Invasive Plant Control and Revegetation Project, City of Portland Environmental Services, 2010. 13. The Chicago Green Alley Handbook – An Action Guide to Create a Greener, Environmentally Sustainable Chicago, CDOT, 2010. 15. Sustainability Efforts. Gardens By The Bay (www.gardensbythebay.com.sg). 16. Sustainability Highlights, Marina Bay Sands Singapore (www.marinabaysands.com). 17. Forest cities: the radical plan to save China from air pollution, The Guardian, 2017. 18. Vertical Forest, Stefano Boeri Architetti (www.stefanoboeriarchitetti.net). 33. www.landezine-award.com/orlysquare-amsterdam

Building a resilient Britain

UK cities are already successfully integrating GU and water management solutions to help mitigate the hazards associated with climate change and the built environment.

The inclusion of GU, the installation of SuDS that store and reuse rainwater, laying permeable pavements to absorb rainwater – all make a marked difference. Consequently, our cities are already becoming more resilient. And by understanding the positive environmental and economic impacts of such initiatives, we can move even closer to achieving multifunctional land use that promotes biodiversity and wellbeing for citizens of the UK – and the world.

UK Government White Paper turns Green

To help understand the importance of ecosystem services (water, soil, nutrients and organisms) in the UK, the government has released the Natural Environment White Paper (NEWP)[20], setting out a clear framework for protecting and enhancing the importance of nature and the positive benefits it provides.

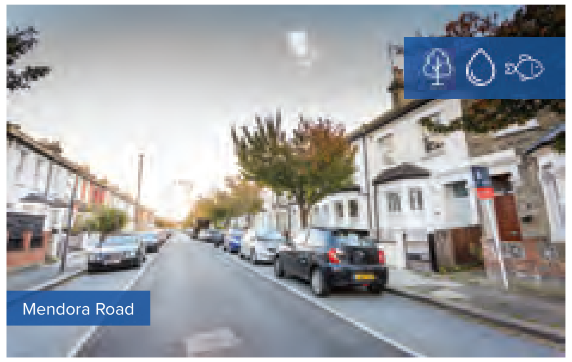
Together with the National Planning Policy Framework 2018 (NPPF)[21], the two directives address strategic priorities that require Public Bodies, Planners and Architects to make positive moves towards sustainable development.

The policies stipulate the promotion of mixed-use developments and making use of the landscape to encourage multiple benefits within urban and rural areas. It's a vision that, for the next 50 years, will include Green Infrastructure, Green roofs, Blue-Green roofs and water management solutions to help manage environmental risk events such as flooding and heatwaves[20] whilst underpinning economic prosperity, health and wellbeing.

20. Natural Environment White Paper discussion document: record response, GOV.UK, 2011. (www.gov.uk/government/news/natural-environment-white-paper-discussion-document-record-response) 21. National Planning Policy Framework, GOV.UK, 2018. (www.gov.uk/government/publications/national-planning-policy-framework--2)

Arundel gardens

Melina Road



Mendora Road

Green Streets

To help alleviate the risk of flooding from West London's combined sewer system which has been built over existing river culverts – known as Counter's Creek – a combination of engineered and soft SuDS have been designed to form the Green Streets Scheme.

Taking in Arundel Gardens, in Kensington, Mendora Road in Fulham and Melina Road in Shepherd's Bush, the scheme – using Polypipe's Permavoid system – helps capture, store and reuse rainwater. Using a combination of products that have been designed to complement the Permavoid System – such as Permatex, Permafoam and Permafilter **(see page 91)** – has allowed the project to introduce and maintain greenery and trees, including rain gardens – whilst having the ability to filter and treat the water before it enters the vast geocellular tanks beneath.

Polypipe Permavoid units **(see page 89)** are manufactured and designed to be durable enough to withstand heavy loads, and so the design includes car parking above, whilst permeable paving is incorporated to capture rainwater run-off at source, directing it to the units below.

Permafoam absorbs the right amount of stored water to passively irrigate the vegetation from below, whilst the Permafilter, with its hydrophilic properties, intercepts contaminants and oil from the road surface above.

Thames Water approved the Polypipe Permavoid System for its light-in-weight construction, allowing for a faster, more efficient installation whilst improving the visual environment, attracting important biodiversity and providing an intelligent multifunctional solution to prevent the historical sewers from flooding.

As a result, the Green Streets project has given the residents peace of mind during extreme weather events whilst providing a pleasant environment to enjoy – one that's now rich in biodiversity.

Positive changes for positive lifestyles

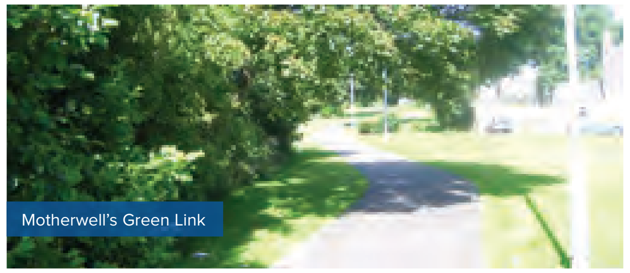
City living promotes a lifestyle that's productive, vibrant and social. Yet, a pleasant stroll, a quiet moment or a jog in the park have dropped further down the list.

It could be that UK cities – not just London – are too busy, too congested and densely built. This has led to a more sedentary way of life, which in turn can affect people's physical and mental health.[6] However, there's a lot we can do to turn this around. Planting closely spaced trees along roadsides can act as a traffic calming measure by creating the illusion of speed.[34] And, as seen in London, the Exhibition Road with its shared surface and signage-free environment has successfully slowed down traffic and transformed the area into a calmer space for pedestrians.

Birkenhead Park

(© Jordan Fraser Photography 2018)

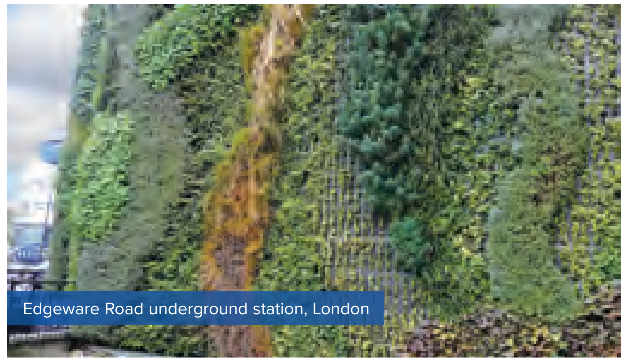
People respond favourably to green spaces[23], trees and traffic-free environments – proven with the creation of the first people's park (Birkenhead Park, 1844, designed by Sir Joseph Paxton). These spaces enhance our quality of life, promote relaxation and improve mental health whilst reducing stress and the cost of healthcare.[22]



Motherwell's Green Link

(© Ross Watson 2012)

In Scotland, Motherwell's Green Link initiative, for instance, is changing lives for the better.[22] Established in 2005, it was the result of a three-year partnership between organisations including Forestry Commission Scotland, Scottish National Heritage and North Lanarkshire Council. Its 7km cycleway has seen a significant increase in exercise in the area whilst also helping towards making them feel safer. The cycleway also creates a green corridor, connecting people, encouraging a more open attitude to spending time outdoors, resulting in a 'social return' of £7 for every £1 invested. In short, the value of creating this space for people to use and enjoy exceeds the financial investment.[22]



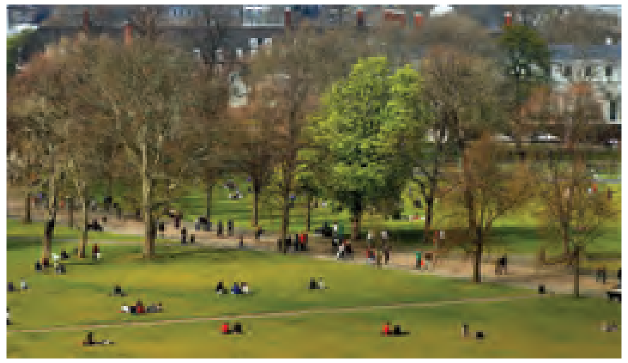
Edgeware Road underground station, London

(© Ian Wright 2012)

Green Wall, London

'Living walls', such as the one at Edgeware Road underground station in London, can make a significant contribution to cooling and insulation.

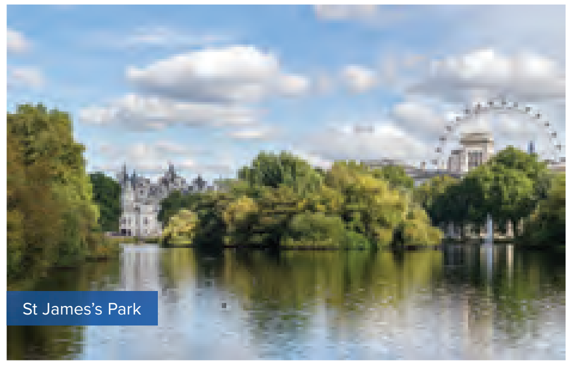
This green wall also cleverly filters pollution, trapping and absorbing harmful fine particles (known as PM10s) on the surface of the leaves.[14] Green walls like this can reduce a building's temperature by around 4°C[14], and even modest tree cover has the potential to reduce Urban Heat Island effect through evaporative cooling and shading.



Less crime and more comfort

Confined spaces and an absence of green landscapes – compounded by poor street lighting – can induce anxiety and a fear of crime, justifiably or not. Incorporating BGU and considered planning within our towns and cities, however, has the potential to overcome discontentment and even prevent crime.

Attractive green spaces are places where people can relax, reflect and come together. Contact with nature – trees, vegetation, wildlife and water – encourage people to form stronger ties with their neighbours.[19] When people are together, surveillance is increased, discouraging 'would be' criminal events. And planning BGU into our urban areas generates wellbeing, helping reduce anxiety, stress and aggression.[7]



St James's Park

(© User:Colin 2012)

Important links to London's green belt

There are 14 green belts around major urban areas in the UK helping to reduce Urban Heat Island effect within the cities they surround. But they're under pressure – especially around London, where it's expected that the capital will need one million new homes in the next 22 years.[29]

However, a series of heatwaves at the turn of the 21st century triggered the All Green Grid Project. Designed to combat the adverse effects that London experienced during the time of the heatwaves – poor health, drought, an increase in animal pests and strain on drinking-water supplies – the Green Grid sets out to support and permit growth. The Grid creates natural urban links between the places people work and live, public transport hubs, the green belt and the River Thames.

Spatial planning on this scale serves to recognise the importance of urban ecosystems within and around our cities and the vital long-term health benefits and resilience they provide.

> The capital will need **one million** new homes in the next 22 years.

Cities Alive – The Case for GI, Arup, 2017.

Salford Quays, Manchester

Greater Manchester – Defra's Urban Pioneer

As part of the Government's campaign for a more sustainable UK, Defra has appointed Greater Manchester (GM) as Urban Pioneer. The programme is part of Defra's 25 Year Environment Plan (25YEP) whereby GM will use its stock of environmental assets – land, forests, water, soil, air and minerals – to provide benefits for its residents.

The use of 'smart' technology will enable the Pioneer to understand the priorities of the public which could include concerns around air quality, water usage and flooding. Whilst an integrated approach, testing new tools and accessing new funding opportunities will all serve to deliver favourable environmental, social and economic outcomes.

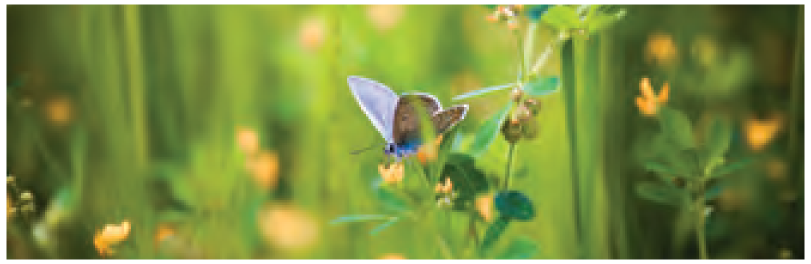
The vision is a current trend that's been covered many times – to enable people to connect with nature within a city environment, to improve their health and wellbeing and maximise economic benefits. It will also introduce effective regulation to achieve positive environmental and economical results, whilst identifying best practice for environmental actions to improve air and water quality and land resource. Low carbon energy will be controlled through smart networks at source or on a community scale. And, unlike trends, the programme is likely to continue after the 25YEP, as this will undoubtedly, and naturally, become the norm on both a local, and indeed global level.[25]

6. Public Health and Landscape: Creating Healthy Places, Landscape Institute Position Statement, by the Landscape Institute UK, 2013. (For Greenlink Motherwell - Forestry Commission Scotland). 7. Greenspace design for health and well-being – practice guide, NHS Forest, Forestry Commission, 2012. 14. Question Time - May, Architect's Choice, 2014. 19. Environment and Crime in the Inner City: Does Vegetation Reduce Crime? 2001 (www.researchgate.net). 22. Public Health and Landscape: Creating Healthy Places, Landscape Institute Position Statement, by the Landscape Institute UK, pg 18, 2013. (For Greenlink Motherwell - Forestry Commission Scotland). 23. The Value of our Green Spaces, The Land Trust, 2016. 25. Greater Manchester Combined Authority (www.greatermanchester-ca.gov.uk). 29. Cities Alive – The Case for GI, Arup, 2017. 34. Human Benefits of Green Spaces, by Dr. Susan Barton. University of Delaware, 2009.

The case for London

Part of the London Green Grid Project, Beam Parklands in Dagenham shows how clever BGU can turn a 53ha flood defence site into a biodiverse wetland and a calm oasis for the general public to enjoy.

Complete with 8km of footpaths and cycleways, the site has become a quality community facility and an enhanced wildlife habitat. Repurposing space like this can deliver favourable returns for our cities – as London continues to prove.



Wild West End

Creating an extensive network of green corridors between large areas of London parkland – already of key natural importance in the area – sets this project apart.

A collaborative effort between several land owners allows the corridors to improve ecological connectivity and enhance biodiversity. The project integrates Green roofs as well as gardens, bird and bat boxes, bee hives and green wall installations.[30]


Palace Hotel, London

(© Jane Dickson 2013)

Green Walls

With London's limited space, it takes clever and creative thinking to plan with GU and water management solutions. Green walls, or 'Living Walls', are perfect space-saving structures that allow available wall space to become natural air coolers, insulators and filters for pollutants.

Both the Palace Hotel and Edgeware Road underground station have green wall installations that actively contribute to reducing carbon and UHI effects – helping to lessen chronic health conditions such as asthma and bronchitis.[31]

24. Cities Alive – Rethinking Green Infrastructure, Arup, pg 75, 2014. 30. London property owners join forces to launch Wild West End ecology initiative, The Crown Estate, 2015. 31. Cities Alive – Economic Benefits, Arup, 2017.

Queen Elizabeth Olympic Park

As part of the Olympic 2012 Legacy, the Queen Elizabeth Olympic Park is to continue its sporting life as a facility to promote sport and support healthy lifestyles. However, just as important is the project's success incorporating green spaces into urban life.

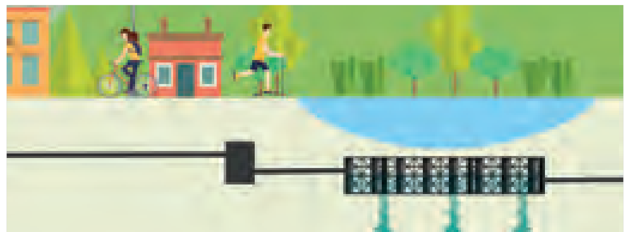
Huge structures and pathways haven't been planned separately – but as part of a large, integrated BGU project. Natural habitats have been created and are now home to varied bird species never before seen in this area[24] with more wildlife predicted as the park matures. And vital Sustainable Drainage Systems (SuDS) s were specifically planned to include important wetland within the park.

Inspiring change through Green Urbanisation

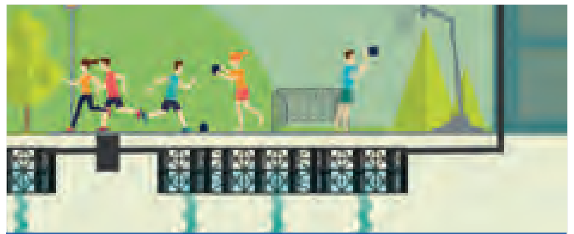
We understand the water management problems cities face, and use our expertise and knowledge to help the industry build resilient cities, introduce Green Urbanisation and make space for water. The earlier we get involved in projects, the better we can work together to achieve world-class BGU, which could provide the following multifunctional benefits:

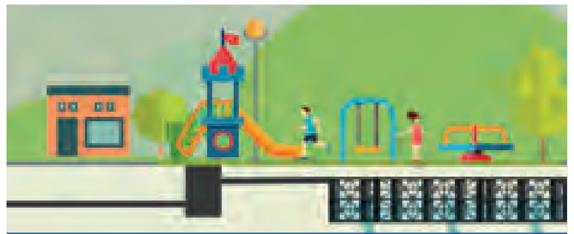

MAKING SPACE FOR WATER


SURFACE WATER MANAGEMENT

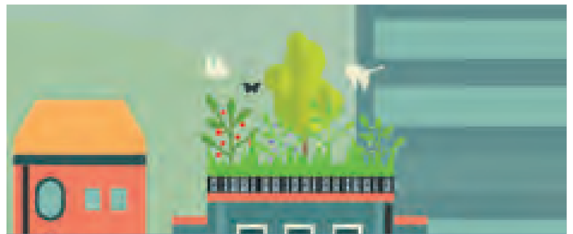

WATER QUALITY

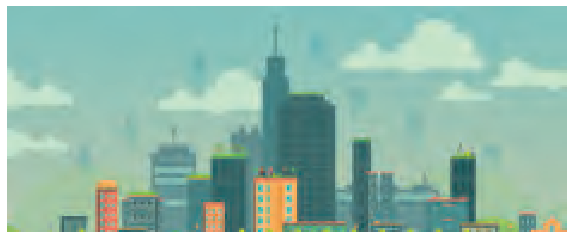

URBAN FARMING


AMENITY


PLACEMAKING


HEALTH AND WELLBEING


BIODIVERSITY


CLIMATE COOLING


ASSET CREATION

MAKING SPACE FOR WATER

When it rains – particularly in extreme cases – the rainwater needs to go somewhere. Unfortunately, in many urbanised environments, rainwater run-off finds its way into our sewer systems causing extreme flooding. This in turn can disrupt natural soakaways, resulting in saturation and further flooding downstream.

It's therefore imperative to design projects that include areas where water can be intercepted and stored. Not simply drainage systems for conveyance, but those that can irrigate green spaces above via wicking technology using our Capillary Cones for example. Systems that provide gardens and amenity at roof level. Bioretention systems, detention basins and rain gardens that can accommodate rainwater run-off whilst attracting biodiversity. And swales – natural and engineered solutions working together, permeable pavements and even sports pitches; which capture, store, attenuate and irrigate whilst cooling the air through evaporation, make that all-important space for and an intelligent way to manage water.

SURFACE WATER MANAGEMENT

With hard man-made surfaces dominating our cities, managing run-off from heavy rainfall is vital to mitigating the risk of surface-water flooding.

That's why we've designed and manufactured infiltration systems to act as soakaways or to capture water at source and store it above and below ground. Our gravity and siphonic systems also allow for storage and filtration for reuse, whilst our attenuation solutions release water gradually to lessen the impact of heavy rainfall on nearby watercourses.

Importantly, boroughs around the UK are now charged a fee by the amount of surface water run-off they allow into waterways and sewers. We are already seeing domestic household charges for surface water run-off caused by car washing. Planners and Developers alike must look to more sustainable and cost-saving ways to store and reuse rainwater before it becomes a problem. In particular, areas around waterways, lakes and ponds need careful consideration with high water tables already posing a threat. Introducing Green Urbanisation, Green Roofs or Blue-Green Roofs can capture water at source and store it for reuse for irrigation, utilities and car washing. Not only will this reduce the strain on potable water supply, but it will also reduce stress on sewer systems.

WATER QUALITY

We understand the challenges Developers face, including meeting industry legislation.

That's why we have engineered a range of water treatment solutions – including filter strips, Permavoid Biomat and Permafilter Geotextile – designed to filter and treat rainwater at source, enhance a natural infiltration system and contaminants. The enhanced quality of the water can then be stored within our geocellular systems, or within an overall 'Roof to River' solution, to be reused.

URBAN FARMING

Growing sustainable produce as part of a community project is becoming more widespread – such as the Union Street Urban Orchard in London.

It's understandable that neglected 'once green' patches of land around our cities and seemingly unsuitable areas of hard landscaping are ignored – with the trend to redevelop what is seen to be 'potential prime land'. Untidy patches of 'greenery' can also suggest 'hard work' and in terms of poor water and soil quality, can hinder progress developing such land – or even cause urban consumer ecosystems to fail.

However, the National Capital Accounting directive can play a part in the planning process of such schemes, ensuring that these small pockets of importance are recognised for the value they bring to people's lives and their wellbeing – not just for those who take part, but for those who benefit from the results. Designing, therefore, with the correct drainage systems it is imperative to ensure that water is managed correctly, sustainably and effectively to improve drainage and soil quality. Our land drainage systems are easy to install and can open up opportunities for otherwise unusable land – ultimately improving crop yields as well as the fabric of the community.

AMENITY

People respond well to green spaces. Even compact streets can be attractive places when trees and clever planting are present. Also, these can even create safer routes for people to cross our roads with distinct green architecture that drivers can recognise as pedestrian entry and exit points.

But to really make a difference whilst making space for water, we've developed products and systems to make spaces for people, too. Blue-Green roofs and podium decks (at ground and roof levels) for example, can be achieved using Polypipe geocellular systems and unique Capillary Cones to manage irrigation. These newly formed green oases can be utilised for multi-use purposes, such as amenity; roof bars, meeting areas for lunch outdoors, children's play areas and sustainable roof gardens. Both commercial and residential developments can benefit from intelligent water management solutions and, whilst not strictly amenity for enjoyment, can include parking for vehicles whilst water below is captured, treated and dispelled safely or reused. And roof applications absorb rainwater at source, reducing run-off whilst enabling water to evaporate more effectively – up to 60% – which helps to cool the surrounding environment.

PLACEMAKING

When creating green spaces for people to use – playgrounds for children, community gardens, green corridors that include cycle paths and walkways – it can be challenging to achieve the right balance.

Our engineered water management solutions combined with soft SuDS techniques can regulate attenuation to ensure the land around natural ponds, for example, is suitable for areas that people can enjoy; usable spaces of greenery, where under normal circumstances, would be wasted land. Permeable paving allows rainwater to filter through to geocellular attenuation tanks below – storing and reusing rainwater for self-sustainable landscaping.

HEALTH AND WELLBEING

Green spaces are calming areas that promote wellbeing and positive health benefits.

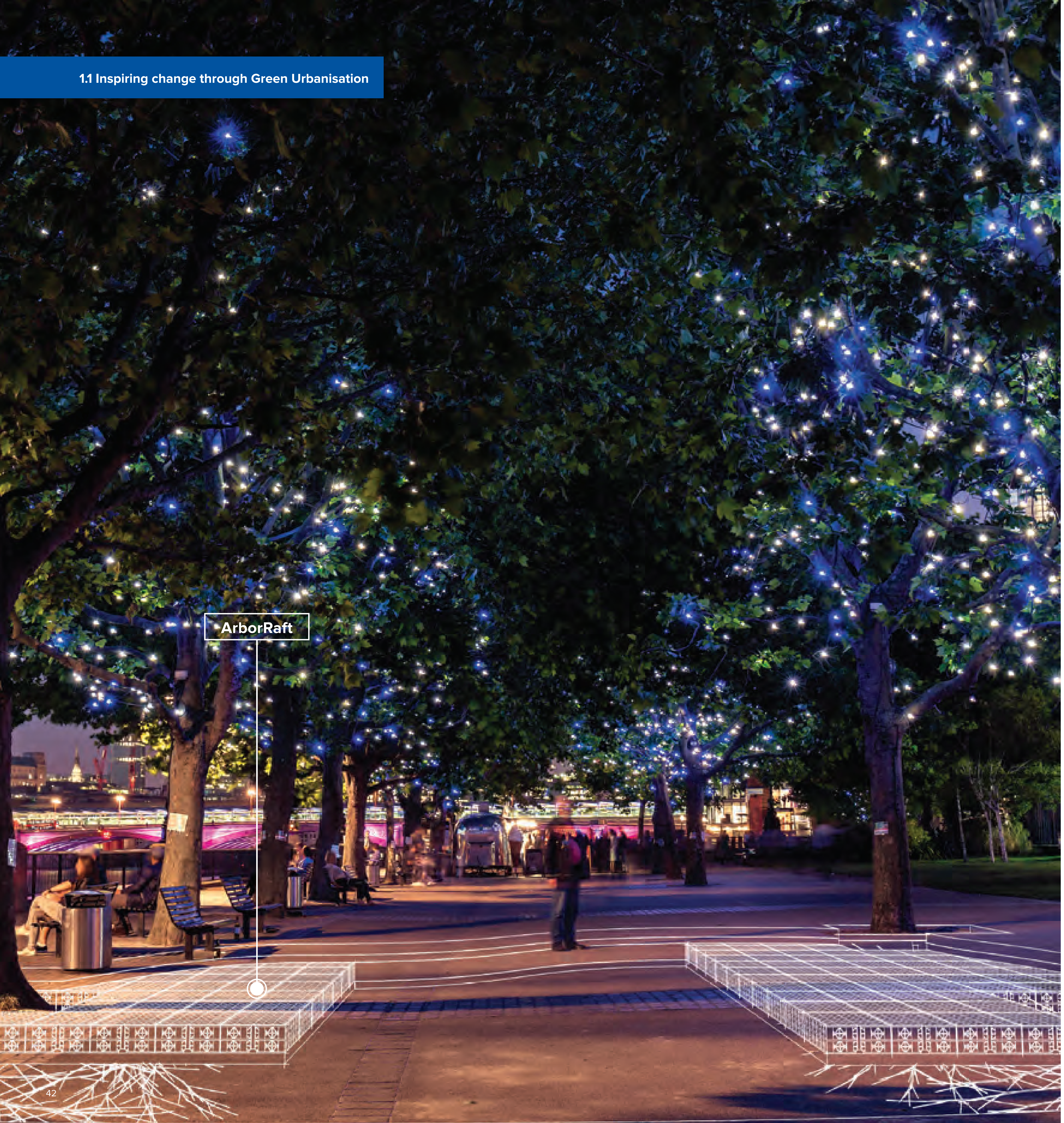
Where space is at a premium, Blue-Green roofs offer relaxation and a sense of community – particularly with rooftop areas designed to give families an opportunity to spend time outside – as well as promoting biodiversity and providing natural insulation for the building. Our engineered geocellular products are designed to collect and store water below podium decks, which can then be reused for the irrigation of trees and vegetation. And because the water is gravity fed, there's no need for pumps.

For larger scale projects, sports pitches for example, have the ability to conceal and capture immense volumes of rainwater, whilst the geocellular tanks irrigate the pitch above allowing the grass to reduce temperatures through evaporative cooling.

BIODIVERSITY

SuDS can provide exciting opportunities. They not only deliver water management solutions to help mitigate the effects of flooding, but also solutions that enhance natural and man-made vegetation to promote biodiversity.

Our systems, either within Blue-Green roofs or at ground level, reuse rainwater to irrigate vegetation, introduce wetlands for wildlife within new developments, and even mimic natural swales. All of which are designed to allow plants and trees to flourish, creating natural environments that attract birds and insects back into our cities.



CLIMATE COOLING

Global warming, climate change and carbon emissions all have an impact on the future of our cities. But foliage, large canopy trees, wetlands and open spaces all help to reduce carbon and, within our cities, can reduce UHI effects and the need for air conditioning.

We continually invest in research and development to engineer products that support these elements. Our sustainability credentials are as important to us as the products we provide, building-in carbon and water-sustainable solutions to help towards a more resilient future for us all. Adopting a circular and micro-economy attitude enables us to manufacture plastic products and systems that extract the maximum value from the resources we use.

We have products and systems that store rainwater at source, reusing it for roof gardens and irrigation which subsequently creates evaporative cooling through the vegetation. We can help with the management of green walls that cool buildings and trap and absorb harmful pollutants. We'll help design engineered SuDS for street tree planting, introducing products that can store and attenuate rainwater below ground and feed and protect the roots of the trees as they grow. And to reduce surface water run-off and flooding whilst promoting greenery and evaporative cooling, we have solutions to simulate swales and treat ground water at source.

ASSET CREATION

Designing GU with water management solutions, particularly at the early stages of a project, not only delivers a project that enhances a city's resilience, but brings prosperity through added value.

Simple design solutions such as creating a network of green corridors between urban areas, for example, can encourage more activity, make for more interesting environments en-route whilst improving ecological connectivity and providing important habitats to attract biodiversity.

Repurposing spaces in buildings or utilising 'dead' space to create amenity is also achievable designing with BGU. With the use of podium decks, geocellular units and water treatment products, roof space and ground level hard surfaces can be transformed into workable and successful leisure and retail spaces. Rooftop restaurants and bars are gradually becoming commonplace, whilst commercial office car parks are hidden beneath workplace gardens that are fed via self-perpetuating, rainwater reuse irrigation systems.

We understand how to achieve these positive outcomes, designing products that make space for water such as Polypipe geocellular systems including Capillary Cones, to be able to create such amenities as rooftop restaurants, parkland above underground car parks and greener spaces within cities. BGU can transform retail spaces to increase trade by up to as much as 40%[27]. Whilst a more vibrant green environment has been found to boost property prices by 2.6% to 11.3%.[28]

Furthermore, they attract inward investment, increase land values and improve planning application and government tender success rates.[26]

> Having a well-managed greenspace nearby was found to result in average property premiums of 2.6% to 11.3%.

Economic benefits of greenspace, Forestry Commission, 2012.

27. Cities – Walkonomics: the High Line effect, Arup, 2015.
28. Economic benefits of greenspace, Forestry Commission, 2012.

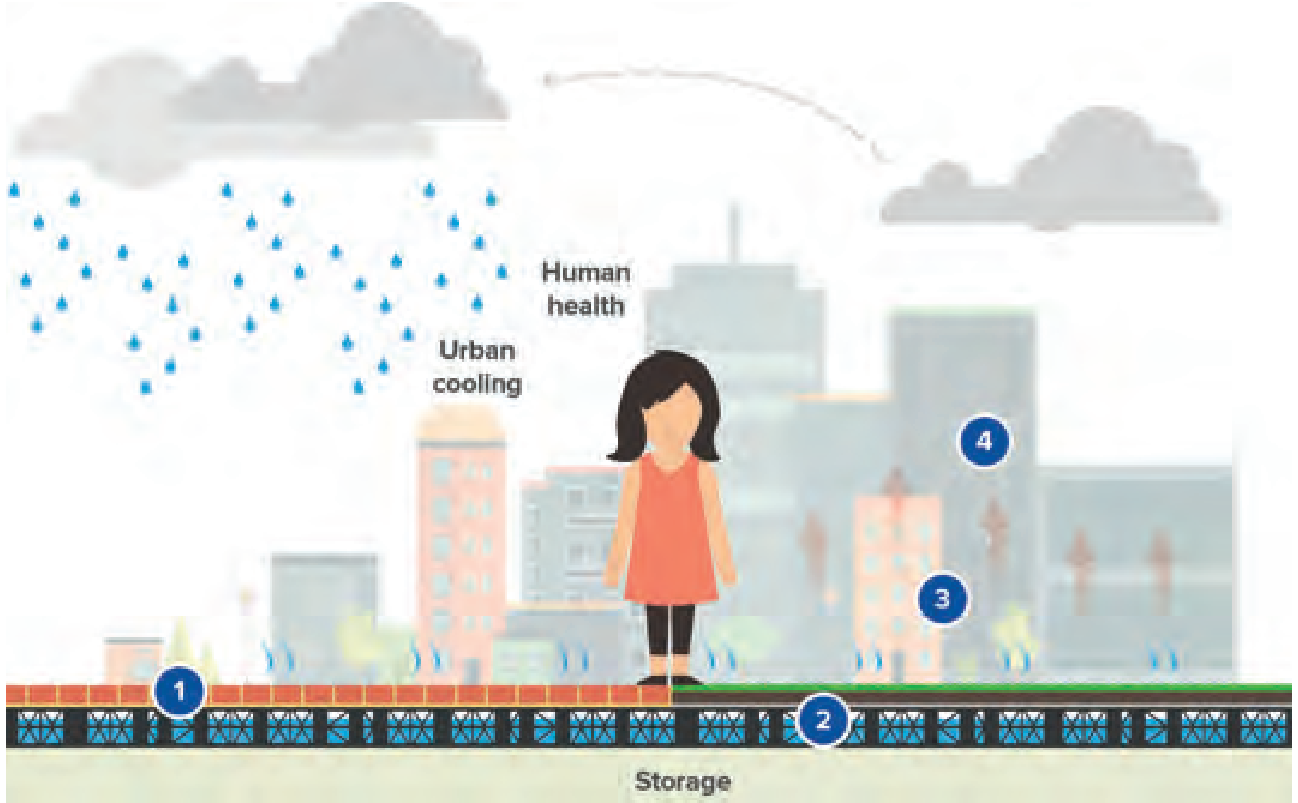
Creating a natural water cycle – on-site

With a culmination of climate change and severe weather events, our urban areas – cities in particular – are at risk of succumbing further to the effects of flooding, drought and the Urban Heat Island effect.

These are challenges that need to be embraced, solutions implemented and positivity reinstated. Our natural water cycle is how life is sustained – and it can only exist with the presence of water in the first place. Green Urbanisation with intelligent water management can self-irrigate, cool the air around it, promote evaporative cooling, create amenity, attract biodiversity and reduce flooding.

Polypipe water management solutions include robust geocellular units combined with a number of innovative additional products to enable on-site catchment, storage, treatment and reuse of rainwater. They're ideal for shallow ground level sites whereby large trees can be planted; with root systems contained and managed and helping towards passive irrigation with Permavoid Capillary Cones. Sports pitches benefit too, capturing rainwater and storing it below the grassed area for irrigation of the pitch; and reused after infiltration for non-potable washroom facilities at the venue. Whilst at roof and podium levels, the geocellular system makes for amenity and green and healthy places to meet and enjoy. Ultimately, the system, at any level, serves to create a natural water cycle on-site.

Providing space to capture rainwater within our urban environments allows the implementation of green solutions which, when connected to form a complete water management system, can create a natural water cycle on-site.



1. Rain intercepted via permeable paving and captured using geocellular units below to reduce run-off.
2. Geotextile stores water and uses Capillary Cones to absorb the water, drawing it up to irrigate vegetation above.
3. Vegetation attracts biodiversity whilst absorbing CO_2 and creating a healthier atmosphere.
4. Vegetation helps cool the air. As the water evaporates from its leaves, it carries the heat away with it.

Polypipe water management systems; either engineered, soft or a combination, are truly multifunctional; helping to reduce the risk of flooding, making space for water and enabling new and much-needed green spaces. By providing plants with perpetually available water, we are able to effectively cool our cities and urban areas and enhance local liveability and biodiversity.

Walthamstow Stadium Development

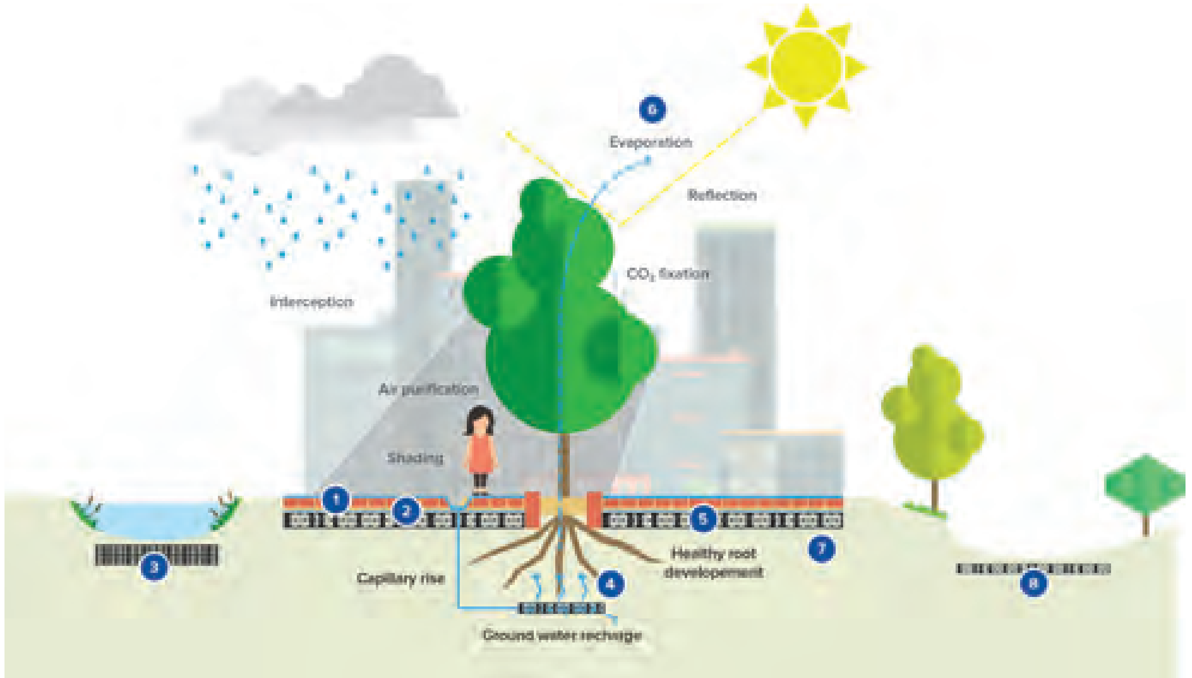
Whiteley Retail Village

Inspiration from evapotranspiration

It's often said that 'nature finds a way'. Indeed, if left to its own devices, nature would take over our cities, our urban areas and everywhere in–between. Of course, allowing this to happen wouldn't be practical for modern human life. But it has always been a part of it. With the continued need to conserve water and bring wellbeing, wildlife and aesthetics back into our cities, trees; especially large canopy varieties, and plants, are more precious a commodity than ever.

The common denominator is water. Without it, there is no Green Urbanisation, no trees, no plants and no natural structure. Evapotranspiration from leaves cools the air, helping to reduce the Urban Heat Island effect; and is why larger canopy trees are more efficient and effective. Leaves also cleverly filter pollution, trapping and absorbing harmful fine particles (known as PM10s – PM relating to Particulate Matter) on the surface of the leaves.[10] Just as important, green space has a relaxing effect on the human mind and a positive effect on human health, with people preferring to live where they can see trees and green spaces.[6]

It's a simple message. Without water, plants stop growing, stop cooling, stop flowering and stop removing pollutants. Through continued research and development, we can design blue with green to ensure we introduce the best systems to include plants and trees into each and every scheme. Catch-Store-Use, just like nature.



1. Rain intercepted via permeable paving and rain garden to reduce run-off.
2. Permafilter Geotextile removes oil and other road contaminants.
3. Polystorm system stores and attenuates water preventing flooding from above natural ponds.
4. Permavoid units provide space for water and use Capillary Cones to irrigate trees above.
5. Air gap to allow roots room to grow without causing damage to surface and protects roots from damage.
6. Helps cool through evaporation whilst providing shade.
7. Soil is naturally recharged with water and also helps cool with evaporation.
8. Natural swales controlled using Permavoid units beneath to store and attenuate.

9. Planting Healthy Air, The Nature Conservancy, pg 1 and pg 108. 10. Question Time - May, Architect's Choice, 2014.

We look to our past to design for the future

Trust. Support. Experience. Innovation. They're not simply words – they're a philosophy. We are one of Europe's largest manufacturers of drainage pipe systems delivering to key industry markets and we have developed the most advanced water management products and systems to respond to the rapidly changing environment. We're proud of our heritage and it's one we continue to build on. We have grown to be able to support the industry at every stage of its growth too, helping our customers in all areas of construction to deliver the best possible project results. And our water management solutions are backed by a market leading service, a pragmatic approach to design and sustainability, and innovative ideas for intelligently engineered results – a project planned with Polypipe, is a project planned with confidence.

2

Master Gunners, Woolwich

Careful planning for realistic outcomes

As with all sectors of our business and the industry, legislation is an area that can affect outcomes.

Here at Polypipe we understand that government directives, budgets and logistics can dictate how projects are managed, what materials are used and the time it takes to achieve the end goal. With the demand for comprehensive water management solutions more prevalent than ever before, we are well positioned to help provide solutions for projects of all sizes.

Pragmatic approach

We have a philosophy that every product and system designed and specified should be perfect for the job in hand. And it's a philosophy that doesn't just relate to quality and value.

We work with you from day one to ensure that the system for your project is the right one. Every project is different, so too are our systems – to ensure your individual water management needs are successful – helping your Green Urbanisation plans to become reality whether commercial or residential.

From design stage through to completion, we adopt a logical approach; providing a transparent and collaborative relationship with you to meet deadlines, overcome possible obstacles and provide a level of service to complement an efficient, quality outcome. And the calibre of our people makes this possible. Our team of qualified drainage specialists, civil engineers and technical support experts provide the most commercially viable and unbiased solution, understanding exactly the range of products to use to engineer the perfect system.

Soft / Engineered SuDS

Mixing engineered and soft SuDS in commercial projects provides developers with the means to maximise the amount of land available for vital amenities such as car parking, playgrounds, and cycle routes while broadening the scope for green areas, creating amenity, useful places where people can meet and relax – whilst encouraging biodiversity and evaporative cooling. Designing your project to include Green Infrastructure is more important now than ever before.

Building-in essential sustainable water management makes for a responsible development – one that can help towards urban spaces becoming more resilient to heavy rainwater events; intercepting rainwater run-off at source and reusing it elsewhere on the development. We can help plan engineered SuDS to provide parking whilst treating and reusing run-off. And introduce sub-surface Polystorm attenuation tanks where space is at a premium to manage open water to provide additional space for recreation or landscaping. The most sustainable schemes, are those that use a combination of these systems; for interception, source control, attenuation, infiltration, wicking for irrigation, reuse and so on.

Simply, at Polypipe, we're proud to manufacture probably some of the most advanced water management systems – to deliver competent, tried and trusted sustainable and intelligent solutions.

2.0 WHY POLYPIPE
2.1 OUR MARKETS
2.2 GREEN URBANISATION & SuDS
2.3 GREEN URBANISATION
2.4 PERMAVOID
2.5 POLYSTORM
2.6 RIDGISTORM-XL COMPONENT CHAMBERS
2.7 ADDITIONAL ENGINEERED SYSTEMS
2.8 TECHNICAL SUPPORT
2.9 MOVING FORWARD

Experience. Reliability. Dedication.

Whilst the inclusion of Green Urbanisation in developments around the world isn't something new, it is still a subject of much speculation. Not least for the perception of difficulty when designing it into a project. However, this isn't necessarily the case and can be cost-effective both in the short and long term.

To help you from the design stage, through planning and to completion, we have a team with the years of experience necessary to deliver. That includes research and development technicians, manufacturing personnel, project managers, field-based staff, dedicated technical support teams, design engineers, key account managers, business development managers, specification teams and fleet staff.

Designing projects with the inclusion of BGU and involving us at the early stages of your project ensures you'll be benefiting from unrivalled experience and reliability from those who understand how best to make space for water. Established as a market leader in the plastic piping industry, you can be confident we understand your water management requirements and can help you maximise them to incorporate multifunctional benefits.

We invest heavily in research and new product development to engineer systems that not only demonstrate exceptional performance but meet building regulations. You can be sure our specialist teams understand exactly what's needed to help make your project a success.

Simply, it's not just about making space for water – it's about making space for water that works.


Horsefield Green, Cuckfield

Everything water. Everything right.

Polypipe water management solutions span the entire SuDS water management train; from Roof to River, from tall buildings to suburban developments and to water courses already at capacity.

The projects we're involved with, as you would expect, are varied and in some cases, unique – where only a customised solution will suffice. And with our very own laboratory and research and development facilities, we ensure all our systems are ready for the toughest challenges – to help bring multi-functional benefits to everyone.

Our geocellular products, for example can be used to create Blue-Green roofs. We've developed solutions that enhance natural and man-made vegetation to promote biodiversity. And engineered water management solutions combined with soft SuDS techniques to regulate attenuation – ensuring the land around natural ponds, is suitable for such amenity as playgrounds.

Standards, regulations and value

We are constantly investing in plastic materials and engineering technology to bring to the industry high quality and unique products.

For example, we utilise the identiPol[42] system to measure the polymeric properties of each batch of recycled material prior to use – the capability of this technology is invaluable to us and to our customers to provide only the highest quality plastic products.

And significant investment in our extrusion and moulding machines as well as new automated processes, has improved reliability and efficiency. Whilst our research into new materials has led us to explore the many possibilities of 3D printing techniques.

Quality is at the heart of our products and systems, they're UKAS accredited and are designed to be lighter in weight than traditional materials, strong, durable and quicker to install, whilst meeting all the relevant standards and accreditations. Which means we can help you achieve the best from your project.

Environmental sustainability and supply chain

We've become synonymous with plastic, but that's only part of who we are. Our continued passion for sustainability is not only in our hearts - it's also in our minds, which has allowed us to create products and systems that help the construction industry move forward faster and easier.

We have invested heavily in the right people and technology and are immensely proud of the developments we've made: for example, our own polymer recycling and processing plant. In 2017 we processed approximately 44,000 tonnes of recycled plastics, saving the equivalent of 44,000 cars CO_2 emissions, when compared with disposal at landfill.

Lighter in weight than rigid materials like concrete and clay, plastic piping and products are not only easy and safe to handle and quick to install, but they also help to reduce fuel consumption and carbon emissions during transportation too.

We ensure our systems meet the balanced scorecard approach to providing value solutions, and all our products are 100% recyclable at the end of their life – and we've earned a silver FORS 'Best Practice for Commercial Vehicle Operators' award for safety, efficiency and environmental protection.

> We never underestimate how critical our supply chain is in helping us deliver a seamless service to you – from material suppliers to our national stockists.

Indeed, we have nationwide stockists to ensure ultimate accessibility to our wide range of products. We train our Merchant Personnel so they understand precisely how our products can make a significant difference when used as a complete system. And we ensure complete traceability for all products via careful supply chain sourcing – bringing you only quality products with service to match.

42. identiPol. www.identipol.com/testimonials

Skills and safety

We place a huge emphasis on the calibre of our people – they are, after all, our most valuable assets.

Investing in people and focusing on engagement remains at the core of our business strategy, with a number of training and development programmes running across all of our businesses, specifically targeting management and leadership development. This ensures that our top-level sales and management teams are fully conversant with new and existing product lines, legislation and systems to be able to provide project-specific solutions. And we invest in continual training to retain specialist levels of design and fabrication expertise. This allows us to deliver the kind of products that meet Health and Safety regulations time after time; for example, we are able to fully fit our large tanks and chambers off-site; complete with innovative safety features such as integral lifting points, step rungs and ladders, toe holds, safety chain assemblies and guardrails. Once completed within our factory-controlled environment, the unit is then delivered to site. This then enables us to reduce transport times and logistics.

Everything we do at Polypipe is designed to make your project run as smoothly as possible, and that means constantly working to discover new ways to design our plastic products and systems to include Health & Safety features.

By its very nature, plastic is lighter in weight than concrete or clay – 94% in piping like-for-like terms – and easy to handle, transport and install.

Water, nature and personal value

Our products are designed and engineered to provide better drainage, innovative application methods and capture and storage for the attenuation and reuse of rainwater.

Ultimately, these water management solutions will provide greener, more enticing places to enjoy; whether a small urban park or a rooftop café. They'll provide multi-use benefits such as car parks whilst irrigating the trees that surround it using unique wicking technology. Cycle paths that can infiltrate water through a permeable paving system – and engineered SuDS that work with soft SuDS to intercept upstream floodwater. Managing rainwater and controlling it will help us to deliver real value, both physical and financial; instilling a feeling of wellbeing and reintroducing biodiversity into urban areas, whilst potentially increasing property prices and attracting inward investment.

To help manage everyday life in the future, we have the products to manage water today.

Porth Station Park & Ride

Key markets

Our market-focused approach to the construction industry and the versatility of our product range, enables us to deliver quality solutions to the Residential, Commercial and Civils and Infrastructure markets.

Our unmatched portfolio offers innovative systems for pressure and non-pressure applications, enabling the movement of water, air, power, chemicals and telecommunications throughout the built environment – helping to deliver health benefits and sustainable results for a resilient outcome.

Westbrook Primary School, Hounslow

Commercial and Public

From schools, hospitals and car parks to shopping centres and commercial and industrial developments. We work in partnership with the industry to provide bespoke water management solutions, from Roof to River.

We also offer innovative products and systems for below ground ventilation. At Westbrook Primary School, for example, Ridgistorm-XL large diameter pipes pre-conditions the air before it enters the building. The air, drawn in through air inlets, provides cool air in the summer and warmer air in the winter with temperatures dictated by those from the soil. The project created 100% fresh air ventilation, providing the school with a more comfortable environment whilst energy consumption was reduced, delivering a more positive carbon footprint outcome.

Our industry-leading expertise and knowledgeable technical solutions teams allow us to provide an unrivalled level of support for every project. So, with the industry's widest choice of water management systems or surface water drainage systems available today, you can be sure that you have our uncompromised support.

Acomb Crescent, Newcastle City Council

Roads and Highways

With higher volumes of traffic, the UK's road network is constantly under review – either for new roads, or adaptations to existing ones. Flooding, especially on motorways, is a major concern and thankfully one that Polypipe has developed SuDS to manage.

With limited available space to accommodate a system that was able to prevent a housing estate in Newcastle from flooding, Polypipe's technical team devised a bespoke solution using Polypipe's Permavoid system. Situated beneath recreational land between the road and river, the Permavoid system; including geocellular units and Permavoid Biomat, intercepts the run-off, traps road surface oils and stores the water before discharging it back into the river at a controlled rate.

We offer a full range of surface water drainage systems, conforming to Highways England standards and specifications to meet the needs of motorways and highway projects.

And from a Health and Safety aspect, our products are lighter in weight than traditional alternatives, making them easy to handle and quick to install. Combined with its availability in longer lengths, it effectively speeds up installation time to reduce road or lane closures.

Residential

Whether for new build or refurbishment projects, we offer a full range of plastic piping systems and products to meet the demands of modern construction environments.

We understand the pressures developers and homeowners face when it comes to approvals and Building Regulations. That's why we share our knowledge to provide carefully tailored solutions for every project – ensuring water management at source, providing SuDS for on-site amenities and enabling water treatment for improved water quality.

We have water management products and systems to help alleviate stormwater flooding whilst storing it and reusing it to reduce the strain on sewer systems; the range also covers above ground drainage systems for rainwater, soil and waste as well as for below ground drainage and flood resilience.

Regent's Place (Houghton Regis)

SuDS: they're a part of us

Under normal weather conditions, soft Sustainable Drainage Systems (SuDS), such as natural swales, ditches and ponds, are capable of managing rainwater. However, in more severe weather, they can become less effective. With the inclusion of below ground SuDS systems, surface water flooding can be reduced.

Polypipe's engineered SuDS are designed to work as an effective solution, either on their own or integrated with soft SuDS, to help address the challenges of surface water flooding – introducing effective, controlled retention, attenuation and infiltration at source and further afield.

Making Space for Water with SuDS

Storm events affect man-made developments as well as the natural landscape. Where storms are particularly extreme, surface water run-off from hard surfaces in urban environments can have an adverse effect on natural drainage further down the line. This can result in widespread, excessive flooding from saturated land, overflowing sewers and a rise in river water levels.

Polypipe's market-leading systems are designed to effectively manage water at source and within areas where large scale water management is required. Polypipe geocellular systems – including Permavoid and Polystorm – are engineered to manage large volumes of water and are adaptable to be able to not only capture and intercept heavy rainwater at source, but to treat it, store it, attenuate it and reuse it.

As with all water management systems, it's as well to design as many into your project as possible to ensure the best possible results. For example, installing permeable paving or filter drains at source to route rainwater to geocellular units below ground, effectively managing stormwater run-off and allowing the system to release the stored water at a controlled rate.

Site control systems use buried storage units that intercept water exceeding that of source control levels, and discharges it at controlled greenfield run-off rates. Stormwater treatment devices can be included within the system, filtering road oils and contaminants from urban surface water run-off. Situated below ground, the geocellular units also free up space above, making land available for amenity and landscaping such as public open spaces – which, in turn, serves to promote community spaces and biodiversity.

Where large scale regional control is required, our engineered SuDS work with soft SuDS – wetlands and water courses – to help mitigate and manage widespread flooding, improve biodiversity and further reduce run-off volumes through natural evaporative cooling.

Planning ahead is key to successful flood control. Adopting a holistic approach to planning ensures all the hard work invested in source control isn't then undone by ignoring possible flood risks around the development and within the wider area. Polypipe can help design your project to deliver a successful and sustainable development – simply by making space for water.

The Polypipe SuDS Water Management Train for Sustainability

The Polypipe SuDS water management train is a simple demonstration of how a holistic system can help reduce flooding, increase natural vegetation and improve evaporative cooling.

It shows that – with strategic thinking, sustainability and resilience – controlling the quality and volume of surface water run-off within urban environments can be achieved.

Brainy drainage

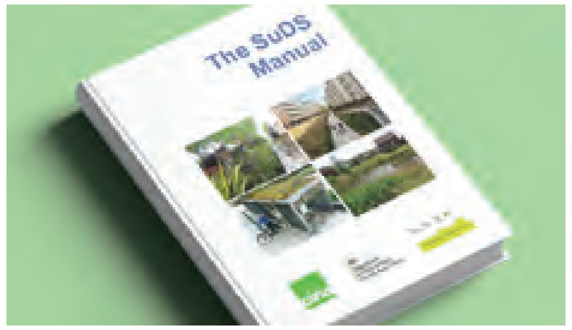
With limited space to store rainwater at ground level in urban areas, Blue-Green roofs offer a simple alternative to underground storage. They can provide additional recreational space, encouraging biodiversity and regulating stormwater management.

Capturing water at roof or podium level allows water to be reused within the building – thereby reducing its use of potable water. The stored water can also be treated, then reused to irrigate Green roofs in dry spells. Which subsequently can cool the air by evaporating water by up to 60% more effectively than if it were at ground level.

One such project that's embraced this approach is Unite Students Stratford ONE. Located near the Queen Elizabeth Olympic Park in London, the project accommodates more than 1,000 students across 28 floors – and features a two-tiered Polypipe geocellular attenuation system that captures the rainwater run-off at source from both the building roof and podium.

Flow control outlets discharge the rainwater into a $30m^3$ buried attenuation tank, constructed with Polypipe's Polystorm geocellular units, at a rate of 42litres/sec – with a built-in 40% capacity as a safety margin in case of a '1-in-100-year' storm event.

Such water-efficient equipment and control of surface run-off can earn several BREEAM points. It's this sort of innovative thinking that will help the sustainability of city-centre buildings – especially where reduced external ground space is too restrictive to incorporate a large, buried attenuation structure.[34]



CIRIA SuDS Manual – leading the way

Government planning policy has recognised the need for SuDS to ensure that flood risk is considered at all stages of the planning and design processes.

The CIRIA SuDS Manual sets out to provide developers with the guidance needed to understand the importance of SuDS. And incorporating the 'four pillars of SuDS' – water quantity, water quality, amenity and biodiversity – developers are best able to consider certain basic requirements as well as emphasising source control techniques and pollution removal.

We have responded to this mandate by developing intelligently engineered, holistic solutions that include geocellular and large diameter pipe systems to meet government directives. As part of these requirements, run-off from any given development must be no greater than the run-off prior to starting it – and that the same run-off should replicate, as far as possible, the natural action of the site towards rainfall.

Furthermore, we have systems that respond positively to environmental impacts, particularly pollutants found in surface water run-off – hydrocarbons, oils, sediments, pathogens and animal waste, for example.

With the support of our in-house Technical, Fabrication and Product Support Teams, we can help you plan with SuDS to meet and exceed legislative requirements from start to finish.

34. Brainy Drainage, Ian Crickmore, Building Control Journal, 2016.

On top of legislation for today's construction challenges

Government planning policy requires flood risk to be considered during all stages of the planning process. Sustainable drainage systems (SuDS) is also identified as a valuable way of mitigating flood risk.

UK legislation relating to land drainage and flood defence is complex, having developed over centuries to provide an allocation of responsibilities and enable resolution of practical problems. Consequently, there are numerous acts and statutes dealing with the environment, local government, and public health. The following section attempts to highlight some of the key legislation, regulation and delivery mechanisms used for water and flood management.

National Legislation & Regulations

Apart from the statutory instruments (Regulations) that transposed EU directives into UK law, the following section summarises the key government and devolved administration legislation and regulations that address the protection of the water environment and management of flooding. It should be noted that overall policy responsibility for flood and coastal erosion risk rests with the following organisations:

England:	Department for Environment, Flood & Rural Affairs (DEFRA).
National Assembly for Wales (NAW):	Natural Resources Wales.
Scottish Executive:	Scottish Ministers, as set out in the Flood Risk Management (Scotland) Act 2009.
Northern Ireland Assembly:	Department for Infrastructure.

EU Legislation

Water Framework Directive

The Water Framework Directive (WFD) established an integrated water policy framework across European Union member states with the objective of protecting all waters, including surface, ground and coastal waters. The directive requires all member states to produce management plans, centred around river basins, with the aim of achieving minimum environmental and ecological objectives.

Groundwater Daughter Directive

The Groundwater Daughter Directive (GDD) clarifies elements of the WFD, relating to the management of groundwater and establishing groundwater quality standards.

Floods Directive

The Floods Directive assists member states in preventing and limiting the effects of floods; requiring assessment of flooding risk to be undertaken, production of flood risk maps and the establishment of plans to manage those risks if identified as being significant.

Flood and Water Management Act 2010 (amended 2012)

The Flood and Water Management Act (FWMA) came into effect in 2010, with the aim of creating a more effective means of managing flood risk and improve water management. The Act confirmed flooding from main rivers is the responsibility of the Environment Agency, in addition to having a strategic overview of all flooding issues within England. It also created Lead Local Flood Authorities (LLFA), which have primary responsibility for flooding from other sources (i.e. surface water, groundwater and pluvial flooding). Schedule 3 of the Act requires sustainable drainage system (SuDS) principles to be implemented on all new developments, in accordance with published national standards that detail the design, construction, operation and maintenance of SuDS. Each LLFA are also required to establish a SuDS Approval Body (SAB) to approve proposed drainage system designs prior to the commencement of construction. Where SuDS serving more than one property meet the national standards, the SAB is required to adopt and maintain the approved system. However, Schedule 3 has not been fully implemented within England and Wales, SuDS policies instead are currently being promoted via the planning system.

Flood Risk Management (Scotland) Act 2009

The Act introduced more sustainable approaches to flood risk management within Scotland; creating more coordinated national and local processes for flood risk management. With new responsibilities given to the Scottish Environmental Protection Agency (SEPA), Scottish Water and local authorities.

The Water Environment and Water Services (WEWS (Scotland) Act 2003

Gave Scottish Water responsibility for SuDS that receive run-off from surfaces within a property boundary, in addition, the Act made SuDS obligatory on all new developments.

Water Industry Act 1991 (Amended 1999)

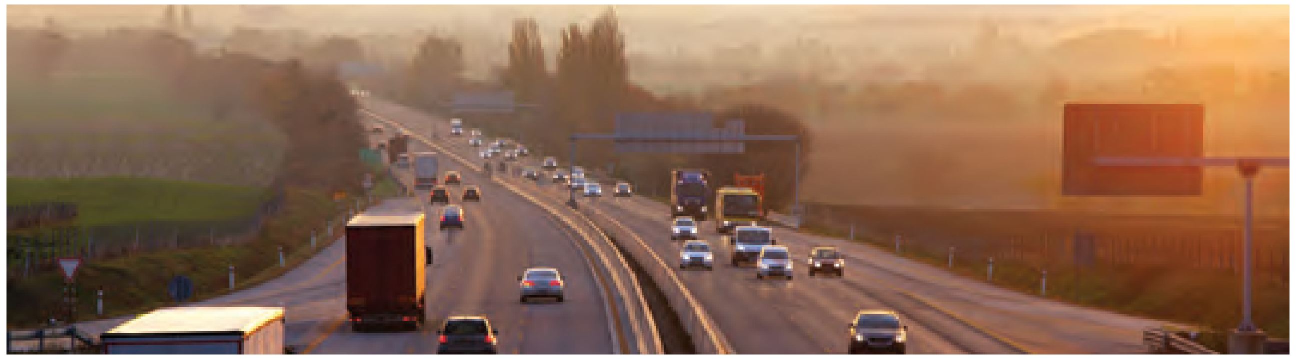
The Act consolidated previous enactments that related to water resources, regulation of the water industry and other miscellaneous provisions. It provides the legal definition of a 'public sewer', which are typically the responsibility of (vested in) a Sewerage Undertaker, who is liable to maintain and empty it.

Water Industry (Scotland) Act 2002

Established corresponding organisations within Scotland, including Scottish Water which is a statutory corporation (owned by the Scottish Government).

The Water and Sewerage Services Act (Northern Ireland) 2016

Section 4 of the Act introduces a definition of SuDS, in addition to providing powers to Northern Ireland Water (NI Water) to adopt SuDS. Section 5 provides further support by giving NI Water the power to refuse surface water connections to the public sewer network where the design or construction of the SuDS does not meet minimum standards, or a suitable alternative is available.



Highways Act 1980 & Roads (Scotland) Act 1984

The Act deals with the management and operation of the road network, with responsibility for the management of road drainage given to highway authorities. Drainage from the trunk road network being the responsibility of:

England:	Highways England.
Wales:	Either the North & Mid Wales Trunk Road Agency (NMWTRA) or South Wales Trunk Road Agent (SWTRA); on behalf of the Welsh Government.
Scotland:	Transport Scotland.
Northern Ireland:	Department for Infrastructure/Roads. The public body responsible for the management of all roads within Northern Ireland.

Planning

Managing the development of land and buildings is the responsibility of the relevant planning authority, whose permission would usually be required prior to the commencement of construction activities. Setting planning policy and operation of the planning system, being the responsibility of:

England:	Department for Communities and Local Government (DCLG); via the National Planning Policy Framework Technical Guidance to the National Planning Policy Framework, provides additional guidance on how effective implementation may be achieved.
Wales:	Welsh Government; via Planning Policy Wales Technical Advice Note (TAN) 15 providing supplementary technical guidance in relation to development and flooding.
Scotland:	Local Government and Communities Directorate, Minister for Local Government and Planning; via the National Planning Framework and Scottish Planning Policy Online Planning Advice on Flood Risk, provides guidance on how the policy should be applied (available at www.gov.scot).
Northern Ireland:	Department for Infrastructure, Planning Policy Division; via the Strategic Planning Policy Statement (SPPS) Planning Policy Statement 15 (PPS 15) provides supplementary policy guidance in relation to minimising and managing flood risk.

With government agencies (i.e. transport, environment protection) and other organisational stakeholders (i.e. Sewerage Undertaker) having a general duty to engage in the development planning process at different stages.

All government agencies are required to implement policies that promote sustainable development. In relation to water management, this includes having a general regard to:

- Mitigating the causes and impacts of flooding, from all sources
- Removing pollutants from urban run-off at source
- Combining water management with green space that include benefits for amenity, recreation and wildlife

With respect to surface water drainage, planning policy stipulates that Sustainable Drainage Systems (SuDS) principles should be followed while formulating development plans. Compliance to published standards being a way for designers and developers to demonstrate that planning advice on development and flood risk has been taken into account.

It should be noted that local planning authorities may have published their own additional guidance, to align national policy with local flood risk management plans.

Building Regulations

Building regulations give minimum standards for the design, construction or alteration of virtually all buildings to ensure the safety and health of people in or about the structure. They also include requirements relating to access, facility provision, minimising energy and water usage and promoting the well-being of occupants.

The regulations are supported by technical guidance, which set out detailed guidance on achieving compliance with the technical parts of the regulations. Surface water discharge from within a building curtilage, the regulations give an order of preference, prioritising the use of infiltration and SuDS techniques over outfall to a watercourse or public sewer; further guidance is given in:

England:	The Building Regulations 2010, Approved Documents H (Drainage and Waste Disposal).
Wales:	The Building Regulations (Wales) 2010, Approved Documents H (Drainage and Waste Disposal).
Scotland:	Domestic and Non-domestic buildings Technical Handbooks (2013); Section 3.3, Flooding and groundwater.
Northern Ireland:	Building Regulations (Northern Ireland) 2012, Technical Booklet N (Drainage).

Standards for Sustainable Drainage (SuDS)

Development

Standards relating to SuDS have been developed by various regional regulatory parties within the UK, including national governments and numerous unitary or local authorities. These standards being:

England:	Non-statutory technical standards for sustainable drainage systems; DEFRA Non-statutory technical standards for sustainable drainage, Practical Guidance; Local Authority SuDS Officer Organisation (LASOO).
Wales:	Recommended non-statutory standards for sustainable drainage (SuDS) in Wales; Welsh Government.
Scotland:	Water Assessment and Drainage Assessment Guide; Sustainable Drainage System Scottish Working Party (SuDSWP). Sewers for Scotland, 3rd Edition; Scottish Water.

The aim of the above standards is to ensure the development of sustainable water management systems that remain functional for their expected design life. In addition to ensuring the ownership and responsibilities for maintenance of a developments SuDS are clearly defined.

Roads

The above standards are applied to developments that may include road drainage, however, they were not written with a focus on long sections of linear infrastructure i.e. the strategic trunk road network. Provision for SuDS on the trunk road network is contained within:

England & Wales:	Highways England, Department for Transport Design Manual for Roads and Bridges, Volume 4.
Scotland:	SuDS for Roads; Sustainable Drainage System Scottish Working Party (SuDSWP).

Surface Water Management

Site-based surface water management is considered an effective tool in mitigating flood risk. BSI have published a number of codes of practice that support the process of integrating surface water management into development plans.

BS EN 752:2008, Drain and sewer systems outside buildings

BS EN 752 takes a more integrated view of sewer system design and its potential impact on the wider urban drainage system and water environment. Assisting engineers in understanding and implementing integrated urban drainage systems and surface water management. The National Annex provides specific information on how to incorporate BS EN 752 principles with UK best practices.

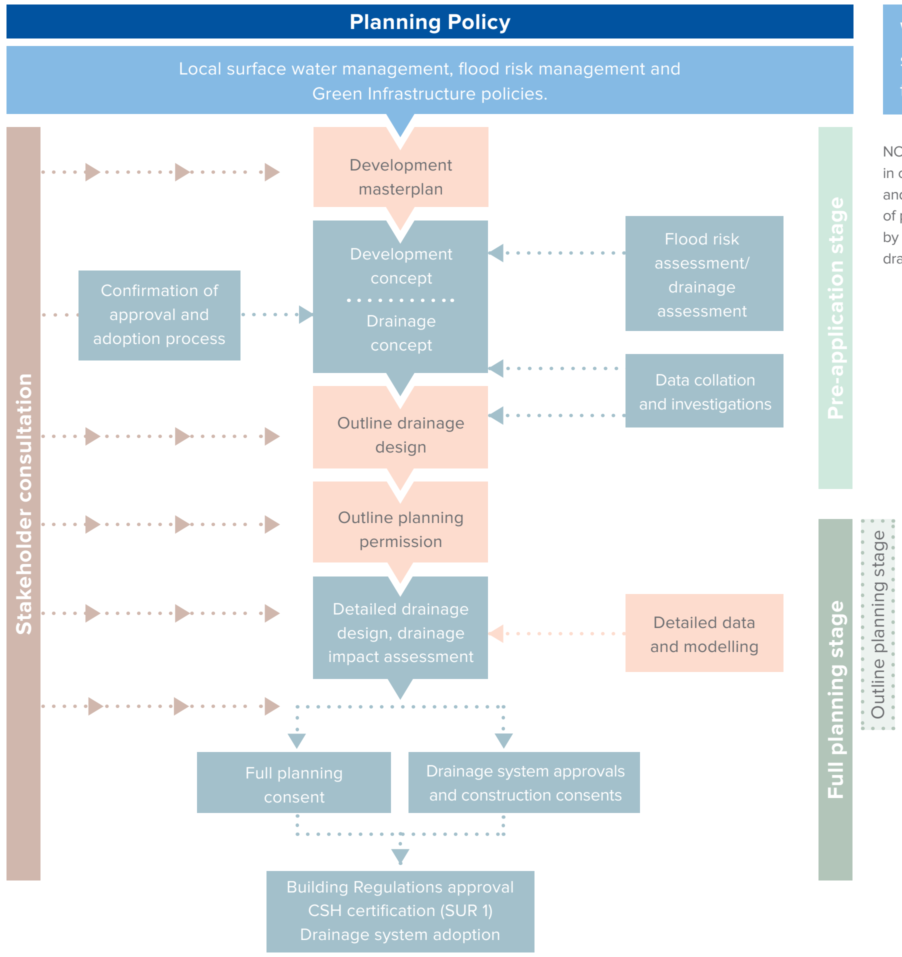
BS 8582:2013, Code of Practice for surface water management for development sites

This Code of Practice provides recommendations on the planning, design, construction and maintenance of surface water management systems for new and redevelopment sites. Developed to support:

- Planners and Drainage Approval Bodies: In setting consistent drainage criteria and principles for developments which will deliver effective surface water flood risk management as sustainably as possible. While contributing towards the delivery of relevant environmental, sustainability and urban design planning objectives for the site and local area.
- Designers: In planning and implementing safe, robust surface water management systems that meet the criteria and principles referred to above.

In addition, the recommendations are based on achieving the maximum environmental and society benefits possible. Through the protection and enhancement of the local environment, mitigation of climate change risks associated with urbanisation and maximising amenity and community value.

The diagram below demonstrates pertinent key links between the development planning process and the drainage system design process, emphasising the stakeholder engagement required throughout.



We can provide help and support at every stage of the planning process.

NOTE: The need for the steps given in colour would depend on the nature and/or scale of the development and type of planning application and is determined by agreement with the planning authority and drainage approval body.

Ref:- Page 8 of British Standard BS 8582:2013.

The Design: General methodology guide

This section explores the factors you would consider when designing a SuDS-compliant drainage system. Here we introduce the many elements potentially needed within the design depending on the scale of development.

Planning and flood risk

What is the general planning approach to development and flood risk?

The National Planning Policy Framework sets strict tests to protect people and property from flooding which all local planning authorities are expected to follow. Where these tests aren't met, national policy is clear that new development should not be allowed. The main steps to be followed are set out below which, in summary, are designed to ensure that if there are better sites in terms of flood risk, or a proposed development cannot be made safe, it should not be permitted.

Assess flood risk:

- Local Planning Authorities undertake a Strategic Flood Risk Assessment to fully understand the flood risk in the area to inform Local Plan preparation.[40]
- In areas at risk of flooding or for sites of 1 hectare or more, developers undertake a site-specific flood risk assessment to accompany applications for planning permission (or prior approval for certain types of permitted development).[40]

Avoid flood risk:

- In plan-making, local planning authorities apply a sequential approach to site selection so that development is, as far as is reasonably possible, located where the risk of flooding (from all sources) is lowest, taking account of climate change and the vulnerability of future uses to flood risk. In plan-making this involves applying the 'Sequential Test' to Local Plans and, if needed, the 'Exception Test' to Local Plans.[40]
- In decision-taking, where necessary, Local Planning Authorities also apply the 'sequential approach'. In decision-taking this involves applying the Sequential Test for specific development proposals and, if needed, the Exception Test for specific development proposals, to steer development to areas with the lowest probability of flooding.[40]

Manage and mitigate flood risk:

- Where development needs to be in locations where there is a risk of flooding (when alternative sites are unavailable), Local Planning Authorities and Developers ensure development is appropriately flood resilient and resistant, safe for its users for the development's lifetime, and will not increase flood risk overall.[40]
- Local Planning Authorities and Developers should seek flood risk management opportunities (e.g. safeguarding land), and to reduce the causes and impacts of flooding (e.g. through the use of sustainable drainage systems (SuDS) in developments).[40]

This guidance on flood risk and coastal change will help Local Planning Authorities in the preparation of Local Plans, and neighbourhoods in preparing neighbourhood plans. It will also be relevant to applications for planning permission and applications for prior approval for certain types of permitted development.[40]

There is information available on the requirements to consult the Environment Agency on applications where there is a risk of flooding – as well as information on what should happen if a Local Planning Authority wishes to grant consent for a major development against Environment Agency advice.[40]

You can find details regarding the role of Lead Local Flood Authorities and when their advice may need to be sought in considering planning applications.[40]

And there is also advice on flood risk in relation to minor developments and change of use, whilst information on climate change and flood risk is available from the Environment Agency.[40]

Source control/Site control/Regional control

SuDS Management Train

A useful concept used in the development of sustainable drainage systems is the SuDS management train (sometimes referred to as the treatment train), illustrated below. Just as in a natural catchment, drainage techniques can be used in series to change the flow and quality characteristics of the run-off in stages.

Source control

The Management Train starts with prevention (preventing run-off by reducing impermeable areas), or good housekeeping measures for reducing pollution; and progresses through local source controls to larger downstream sites and regional controls.

Run-off need not pass through all the stages in the management train. It could flow straight to a site control, but as a general principle it is better to deal with run-off locally, returning the water to the natural drainage system as near to the source as possible.

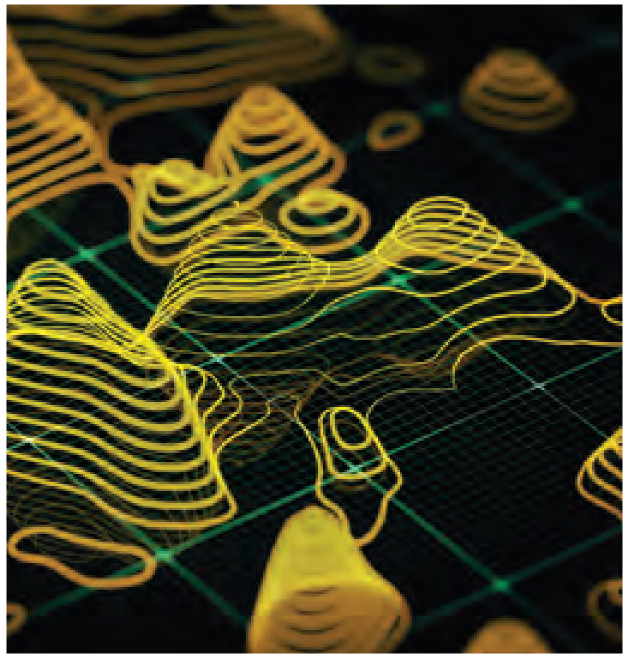
Only if the water cannot be managed on-site should it be (slowly) conveyed elsewhere. This may be due to the water requiring additional treatment before disposal or the quantities of run-off generated being greater than the capacity of the natural drainage system at that point. Excess flows would therefore need to be routed off-site.

Regional control

End-of-pipe solutions where run-off is directly discharged to a wetland or pond should be avoided where possible, as these end-of-pipe components are likely to be larger, more expensive and potentially receive faster run-off flows and, subsequently, higher levels of pollution. SuDS design requires a balancing of different options, often depending on the risks associated with each course of action. The risks of an area flooding have to be balanced with the costs of protecting the area from different levels of floods.

The Management Train concept promotes division of the area to be drained into sub-catchments with different drainage characteristics and land uses, each with its own drainage strategy. Dealing with the water locally not only reduces the quantity that has to be managed at any one point, but also reduces the need for conveying the water off the site. When dividing catchments into small sections it is important to retain a perspective on how this affects the whole catchment management and the hydrological cycle.[41]

40. www.gov.uk 41. www.susdrain.org



Topography

SuDS Management Train (Refer to The SuDS Manual (C753) Section 7.5.1)

Define site and development characteristics

It is important to assess the site for the SuDS scheme before design begins. Where SuDS are to be retrofitted, this should include existing roof areas, hard surfaces, green spaces and land ownership boundaries, in order to make the best use of the space.

This step has two elements:

- Characterisation of the site – development of an understanding of relevant features of the site and the surrounding area that could influence the SuDS design criteria and design options
- Characterisation of the development – development of an understanding of relevant features of the proposed development that could influence the SuDS design criteria and design options

Site topography

Do the site contours mean that flow paths will naturally occur in particular locations? Are there any low-lying areas where water will naturally accumulate? Are there any particularly flat or steep parts of the site?

Topography is a good indication of existing natural drainage pathways and will often help define appropriate natural routes for the surface run-off to follow, in order to efficiently drain the site from higher to lower levels using surface gradients, without relying on extra infrastructure or pumping.

Particularly steep slopes may not be suitable for conveyance routes, without measures to reduce gradients and/or flow velocities, and the siting of storage systems on slopes may require embankments, which should be avoided where possible.

Identification of low-lying areas will demonstrate where water will naturally accumulate, and these may be good locations for siting storage areas. Local historical knowledge and records of surface flooding will be valuable for this process.

Guidance on designing for both sloping and very flat sites is provided in Sections 8.4 and 8.5 respectively.

(The SuDS Manual (C753) page 102 Part C: Applying the Approach)

Design objectives – peak flow control/volume control

Designing for long-term storage (Refer to The SuDS Manual (C753) Section 24.10)

General Description

Additional run-off volumes from developments can cause increases in flood risk downstream of the site, even where peak flows from the site are controlled to green field rates (The SuDS Manual (C753) Section 3.1.2).

Therefore, for extreme events, in addition to the standard for controlling the peak rate of run-off, there is also a standard that requires run-off volume control for the 1:100 year, 6-hour storm event (The SuDS Manual (C753) Section 3.3.1). This is particularly critical for catchments that are susceptible to flooding downstream of the proposed development.

The difference in run-off volume between the development state and the equivalent green field (or possibly pre-development state where this is considered to be acceptable) is termed the Long-Term Storage Volume. It is this volume that should be prevented from leaving the site (via rainwater storage and/or infiltration) or, where this is not possible, controlled so that it discharges at very low rates that will have negligible impact on downstream flood risk. Only the green field (or pre-developed) run-off volume should be allowed to discharge at green field (or pre-developed) rates.

Where there is extra volume generated by the development that must be discharged (because there are no opportunities for it to be infiltrated and/or used on-site), this volume should be released at a very low rate (e.g. < 2 l/s/ha or as agreed with the local drainage approving body and/or environmental regulator) and the 1:100 year green field allowable run-off rate reduced to take account of this extra discharge (Kellagher, 2002).

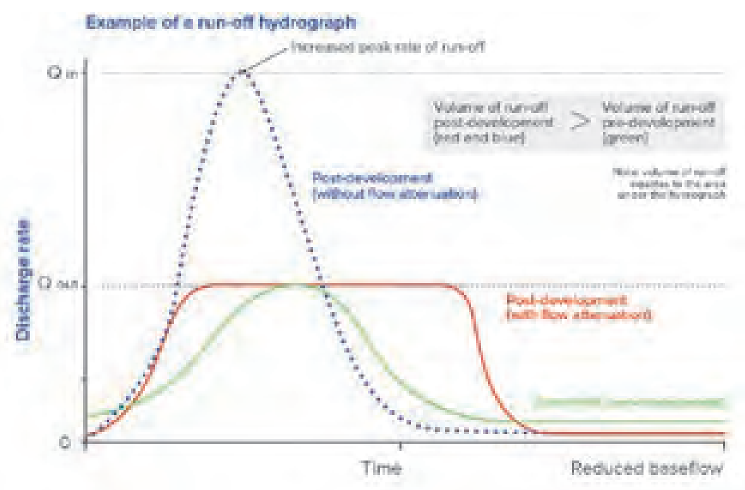
An alternative approach to managing the extra run-off volumes from extreme events separately from the main drainage system is to release all run-off (above the 1 year event) from the site at a maximum rate of 2 l/s/ha or QBAR, whichever is the higher value (or as agreed with the drainage approving body and/or environmental regulator). This avoids the need to undertake more detailed calculations and modelling.

Kellagher (2002) demonstrates that if discharges are not limited to less than 3 l/s/ha, the drainage system will generally not be effective at retaining sufficient water on the site to prevent an increase in flood risk in the receiving catchment. A discharge limit of 2 l/s/ha (or QBAR, which allows for higher discharge rates for specific soil types) has generally been accepted as an appropriate industry standard in the UK, unless alternative site or catchment specific limits are agreed based on local risk evaluation.

(The SuDS Manual (C753) page 533)

Design objectives – water quantity

- To manage quantity
- Prioritise discharge
- Control how fast the water is discharged from a site (peak run-off rate)
- Control how much run-off is discharged from a site (run-off volume)
- Include interception – reducing volume from majority of small events up to 5mm



Design objectives – prevention (Refer to The SuDS Manual (C753) page 51)

When designing drainage systems that incorporate SuDS, it is important to consider pollution prevention strategies.

Pollution prevention should follow a hierarchical approach:

1. Avoid the use of materials and activities that generate pollutants
2. Minimise the use of materials and activities that generate pollutants
3. Prevent pollutants mixing with rainfall
4. Capture pollution within the drainage system for removal, treatment or clean-up and rehabilitation (where required)

Pollution prevention strategies are methods used on-site to manage pollution at source. These strategies may be part of:

- The approved site design or operational strategy, required in order to reduce the environmental risks to acceptable levels
- Standard operational best practice of the site users and/or operators
- Community strategies promoted by local environmental bodies to raise awareness of the risks posed by pollutants in surface water run-off and actions that can be taken to minimise them

The strategies can range from simple common sense working practices built into the site maintenance methods to the use of proprietary treatment systems/products which treat the water depending on the particular site requirement.[2]

Site challenges

Permavoid applications

The geocellular systems from Polypipe can be incorporated into the full range of traffic conditions, from domestic driveways to HGV applications and is suitable below permeable and impermeable asphaltic, block paved or concrete paved areas. The Permavoid system complies with the requirements of BS 7533-13 and incorporates a high vertical compressive strength of 715 kN/m² and lateral compressive strength of 156 kN/m².

High water tables

High water tables and even perched water at shallow depths, require specific design and construction measures to avoid issues such as flotation of attenuation structures, and often prevents the use of soakaways. Anti-flotation and temporary dewatering measures are invariably very expensive. The Permavoid system can often provide the attenuation or infiltration solution for such projects by avoiding groundwater issues.

Contaminated land

Redevelopment of brownfield sites is commonplace and issues of ground contamination often go together simultaneously. Permavoid structures can negate the need to excavate into contaminated soils, a process that would otherwise incur significant costs in on-site remediation or off-site disposal, as well as associated environmental issues.

Excavation of hard rock

Excavation of hard rock is usually expensive and slow. However, Permavoid is ideal for use on sites that are underlain by hard rock at shallow depth as the systems can be incorporated into the pavement construction. This invariably avoids any net additional excavation for the drainage system.

Shallow outfalls

Shallow Permavoid solutions can very often avoid the need for pumping that might otherwise be required with conventional drainage or deep attenuation tank solutions. Pumped solutions can be costly to install and maintain and are considered to be environmentally unsustainable.

Limited access sites

The Permavoid system can be easily man-handled into place without any heavy lifting or off-load equipment. The footprint of the structure does not have to be square; segmented tanks can fit into the available space.

Ground stabilisation

Due to their high compressive strength and bending resistance within the joints, Permavoid cells create a horizontal, consistent structural raft providing a stable structure.

Soft landscaped areas

The Permavoid system can be used to provide pre-treatment of stormwater run-off before it enters a swale, dry basin, pond or wetland (Diagram 1). It is even possible to install Permavoid below swales and dry basins to improve treatment and increase storage capacity (Diagram 2).

Diagram 1

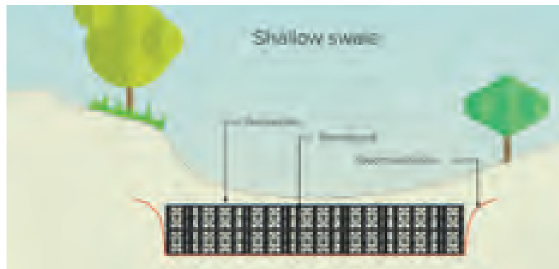


Diagram 2

Public open spaces

Acting as both a sub-base replacement system and drainage component, the Permavoid system is capable of providing maximum attenuation and infiltration for both natural and artificial surfaces and is able to integrate more effectively into site-wide sustainable drainage systems. The result is a sustainable development in line with the DEFRA national standards for delivery of sustainable drainage systems.

Driveways

Any domestic driveway or front garden over 5m² that is being paved must incorporate SuDS to minimise the risk of flooding. The Permavoid system, used in conjunction with permeable paving, can help adhere to these requirements whilst allowing a wide range of landscaping options.

2. CIRIA SuDS MANUAL C753 November 2015.

Limited space

SuDS can be utilised on any site even with limited space:

- There are many different approaches to SuDS
- By integrating the SuDS into the development there should be space
- Look for opportunities for storage – the best systems usually have small features scattered around the site
- When designing for the urban environment, SuDS can make an important contribution to placemaking
- Good design maximises the use of available space
- SuDS can be used in urban areas
- Varied approaches depend on constraints – combination of approaches will work best
- Mix of engineering and landscaping will produce the best results
- The less space there is the more imaginative and flexible you have to be
- The less space there is the more reliance is placed on Green roofs, permeable surfaces, tanks (preferably with reuse) and bioretention
- Don't be afraid to use proprietary systems where they are appropriate
- Multifuntionality is a key requirement
- Possible problems – water has to cross ownership boundaries
- Managing this is the key to success

Maintenance

Introduction (Refer to The SuDS Manual (C753) Section 32.1 Page 691)

Many SuDS components are visible on the surface, form part of the overall site landscape and include a range of habitats. Depending on the design, maintenance regimes need to take account of the wider landscape context of amenity and biodiversity, as well as drainage requirements. The maintenance activities required to deliver the desired amenity, for example, may exceed those required to deliver the designed water quantity and water quality performance. In such cases, this needs to be recognised by those responsible for delivering and maintaining that functionality. Where SuDS components are hard surfaces or below ground, the maintenance will generally be based on engineering requirements.

For the purpose of this manual, maintenance refers to:

- Inspections required to identify performance issues and plan appropriate maintenance needs
- Operation and maintenance of the drainage system
- Landscape management
- Waste management associated with contaminated silt and other waste materials resulting from maintenance

All maintenance will need to take the protection of habitats and associated ecology into account (The SuDS Manual (C753) Chapter 6). Maintenance regimes should be regularly assessed (e.g. once per year) to make sure that the approach is still meeting the drainage, landscape and any other objectives. This may result in changes to the maintenance of a feature or area. For example, more frequent vegetation management may be identified where vegetation growth is obstructing highway sight lines.

The function of the surface water management system should be understood by those responsible for maintenance, regardless of whether individual components are below ground or on the surface. When problems occur in vegetated components on the surface, they may be obvious and can be remedied using standard landscape or engineering practices. However, this is not always the case – particularly with more complex systems such as bioretention systems and permeable surfaces. If any system (whether above or below ground) is properly designed, monitored and maintained, performance deterioration can usually be minimised.

Ease of maintenance and access is therefore a necessary and important consideration of SuDS design (not least as part of CDM requirements to ensure that maintenance can be undertaken safely). Sufficient thought should be given to the likely required maintenance over the design life of the SuDS and its funding during the feasibility and planning stages of a scheme (The SuDS Manual (C753) Chapter 35). In particular, the following requirements should be given full consideration:

- Maintenance access – ensuring appropriate and permanent access to all points in the system where future maintenance may be required
- Forebays and/or appropriate pre-treatment systems to help trap sediment
- Appropriate provision for temporary drainage, if required, during sediment management or other maintenance activities
- The availability of storage and disposal areas for green waste, such as grass cuttings and organic sediments

Appropriate legal agreements between adoption and maintenance organisations that define maintenance responsibilities are presented in Shaffer et al (2004). Maintenance Plans will often be required as a condition of planning for the site. For example, many buildings are required to achieve a high BREEAM rating and a landscape management plan (LMP) is a mandatory requirement to achieve this. Planning Authorities will include this in a planning condition.

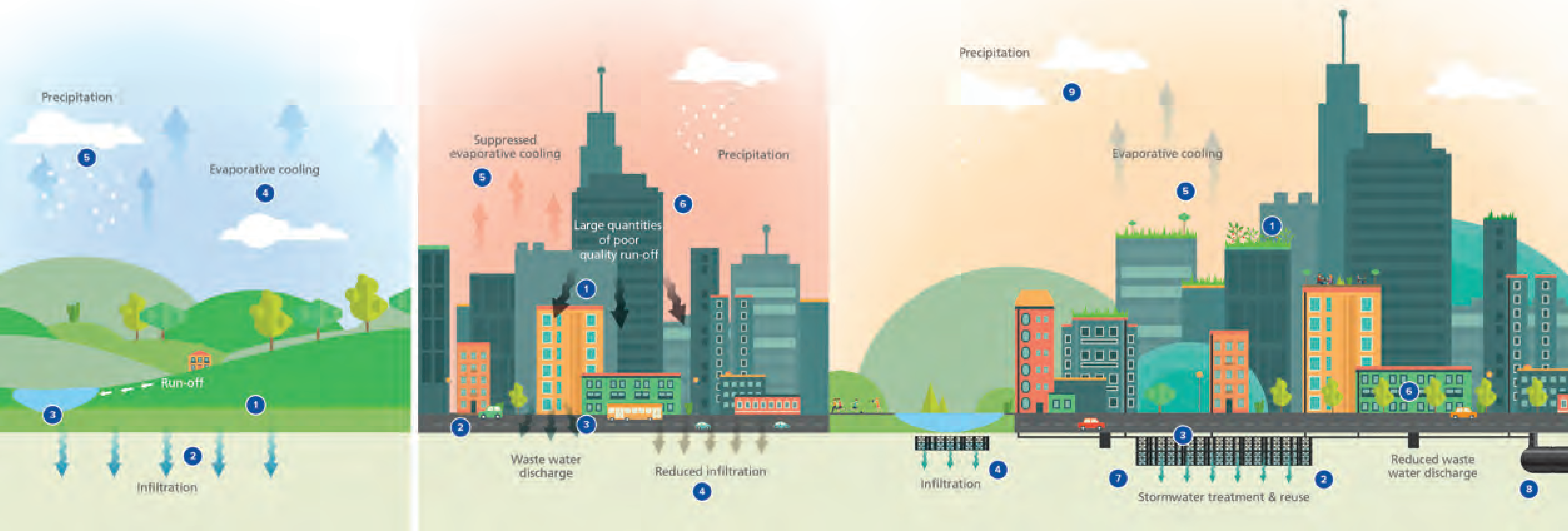
The LMP can also form a useful tool for public or client engagement with SuDS and help them to understand the wider benefits of the system. They can include the provision for ecological re-survey, tree inspection and works and information about how the system delivers multiple benefits.

(The SuDS Manual (C753) page 691 Operation and maintenance)

Setting the scene

Water management solutions within urban landscapes are imperative if a natural water cycle is to be retained. As the illustration shows, rainwater within the natural landscape is allowed to run-off into ponds and filtrate naturally into the soil.

The vegetation and trees then use the water to cool the air through evaporative cooling to create a natural water cycle. Installing water management solutions into our cities shows how we can help mitigate some of the challenges of climate change and urbanisation.



Natural landscape

1. Rain intercepted via grass and soil
2. Soil quality retained through infiltration
3. Run-off captured and naturally controlled via ponds and wetlands
4. Evaporative cooling achieved through vegetation and tree leaves
5. Oxygen released and cooler air condenses causing precipitation

Urban landscape

1. Rain trapped on hard surfaces causing large quantities of poor-quality run-off
2. Large amounts of rainwater intercepted via sewers – adding strain and flooding
3. Flooding on roads and other hard surfaces
4. Reduced infiltration creating poor soil quality
5. Significantly supressed evaporative cooling leading to poor precipitation
6. Trapped and stored heat within concrete causing Urban Heat Island effect

Sustainable landscape

1. Rain captured at source via roof gardens, geocellular tanks and ponds
2. Large amounts of rainwater intercepted via permeable pavements, gulleys and filter strips allowing filtration into the soil below or into geocellular tanks
3. Permafilter geomembrane used to treat and remove oil and road contaminants
4. Sewers relieved of over-saturation with ponds discharging into soil below and geocellular units
5. Evaporative cooling achieved through Capillary Cones drawing water from geocellular units to irrigate vegetation and trees above
6. Urban Heat Island effect reduced through shading from trees and evaporative cooling
7. Soil quality retained through infiltration
8. Run-off captured, stored and reused for non potable purposes
9. Evaporative cooling achieved to create precipitation

Good water management together with Green Urbanisation is the future

Sports pitches on roofs that can irrigate themselves whilst reusing rainwater to reduce the strain on potable water. Permeable pavements that intercept rainwater run-off at source. And bioretention systems that remove contaminants from surface rainwater whilst creating wildlife habitats and green spaces. They're just a small part of a multi-density landscape that could benefit from our multifunctional water management solutions.

High density

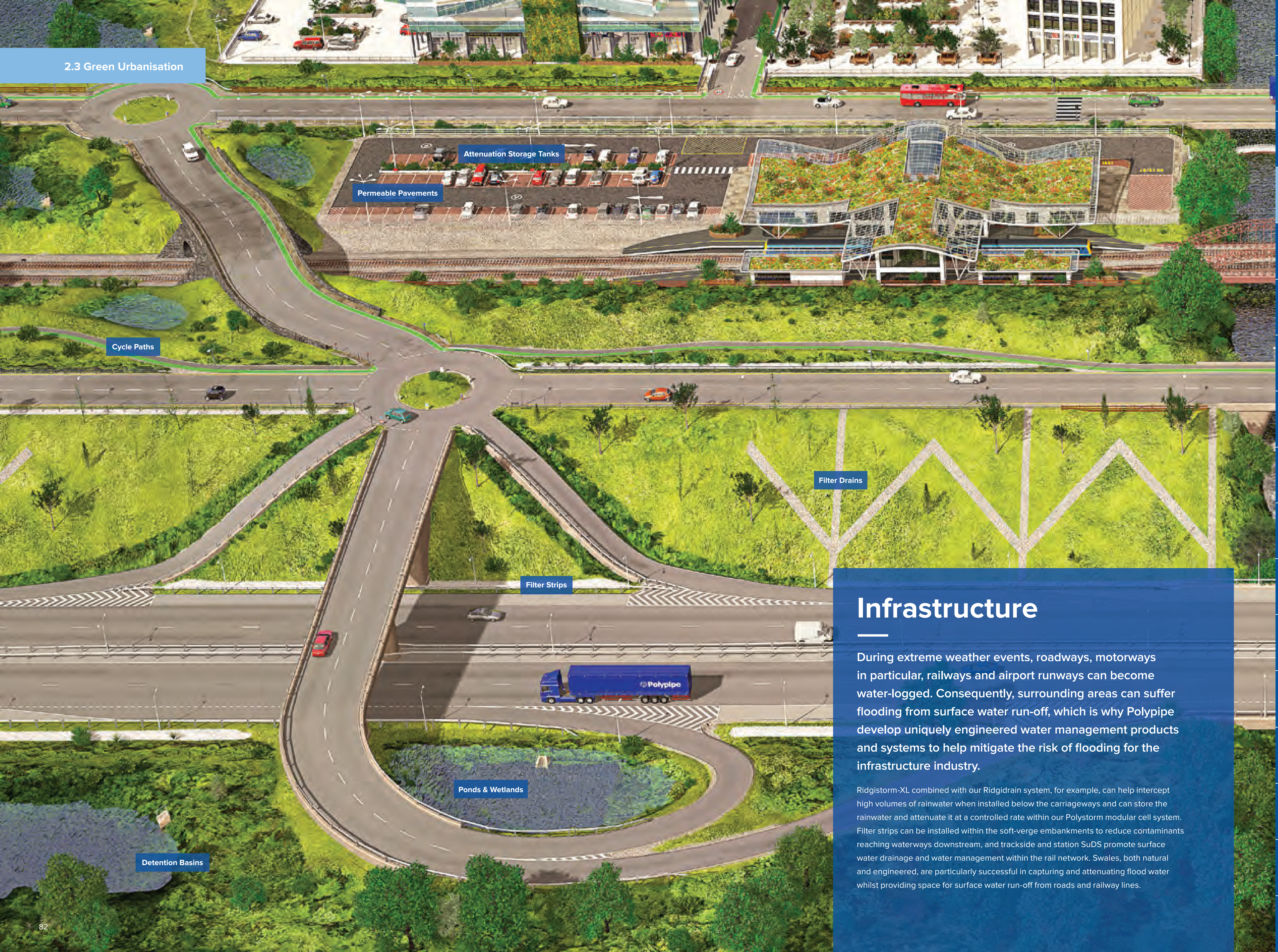
With hard man-made surfaces dominating our cities, managing run-off from heavy rainfall is vital to mitigating the risk of surface-water flooding. Densely populated urban areas, tall, close-grouped buildings and narrow road ways – it would seem Green Urbanisation in this environment would be impossible to include; or tricky at the very least.

However, our tall building solutions – such as our Polypipe geocellular systems – can be utilised together with a portfolio of complementary engineered products to create roof gardens and amenity at roof and podium levels. The system also enables capture, treatment and attenuation of rainwater that can also be reused for toilet flushing in the same building. And at ground level, our below ground systems intercept surface rainwater run-off at source, helping to alleviate flood risk whilst making space for planting large trees. Even a retro-fit scheme can bring multifunctional opportunities, but whichever application you choose to include Blue-Green Infrastructure, we have the systems to make it happen – more sustainably.

Low density

Our range of water management products are engineered to control rainwater from Roof to River. It's what's known as the SuDS Management Train and in areas of low density landscaping, such as residential housing and suburban amenity, it's as effective in controlling the risk of floods around homes as it is in nearby green areas.

Our Ridgistorm-XL range of component chambers for example, work with our Ridgistorm-XL pipes to control the movement of stormwater. Depending on the pre-fabricated chamber you need, the water can be discharged at a precise rate, can limit or isolate flows within surface water or sewer systems and help filter out silt and leaves, protecting downstream drainage systems and the local environment. To intercept rainwater at source, Permeable pavements drain the excess water into Polypipe geocellular storage cells below ground. The same water can then be controlled via the system to irrigate lawns, vegetated verges and street trees. Multi-use Games Areas (MUGAs) can be created on top of our geocellular units to provide leisure space that can also intercept flood water from upstream. Whilst rainwater storage can be afforded below car parks and permeable cycle paths. Our engineered SuDS can be specified alongside soft SuDS to help control wetlands and ponds from flooding – amenity such as playgrounds on ground that would ordinarily be unusable can be realised. And bioretention systems remove contaminants from surface water run-off, attracting wildlife and creating wellbeing at the same time.



Infrastructure

During extreme weather events, roadways, motorways in particular, railways and airport runways can become water-logged. Consequently, surrounding areas can suffer flooding from surface water run-off, which is why Polypipe develop uniquely engineered water management products and systems to help mitigate the risk of flooding for the infrastructure industry.

Ridgistorm-XL combined with our Ridgidrain system, for example, can help intercept high volumes of rainwater when installed below the carriageways and can store the rainwater and attenuate it at a controlled rate within our Polystorm modular cell system. Filter strips can be installed within the soft-verge embankments to reduce contaminants reaching waterways downstream, and trackside and station SuDS promote surface water drainage and water management within the rail network. Swales, both natural and engineered, are particularly successful in capturing and attenuating flood water whilst providing space for surface water run-off from roads and railway lines.

Making the connection with Water Management Solutions

Seeing is believing. Our model green city illustrates the differences between high density and low-density urbanisation and the infrastructure that connects it. However, it's more pertinent, and indeed important, to consider how water connects the three areas.

Without control systems in place – capturing water at source, controlling it and reusing it – rainwater run-off would simply drain into sewers, travel beneath the roadway and continue to the river and waterways. And with the added strain of hard surfaces from the transport infrastructure, flooding would occur – bringing with it contaminants and oils from the road surfaces. At first glance, it may seem like making space for water and treating it, especially within the high-density environment, could pose significant challenges. But it doesn't have to. Here we show how good water management, together with Green Infrastructure design can be beneficial as well as being cost-effective – and how it can be achieved simply and effectively.

Polypipe engineered SuDS are designed to work within a limited space situation as well as more accessible landscapes. Blue-Green roofs, hidden geocellular units above and below ground, concealed systems and engineered SuDS that complement natural soft SuDS, are all playing a part. Working together as an integrated 'source', 'site' and 'regional' control system.

It looks like the future. But it's simply good water management.

To understand how our systems can help your scheme, visit our interactive city at polypipe.com/green-infrastructure or call 01509 615100.

Good Water Management Design, delivers Green Urbanisation

The ultimate goal for any new development, redevelopment or retro-fit project, should be to ensure there's space for water and that there's an intelligent way to use it.

Particularly in new development design, there's an opportunity to maximise space for multifunctional use. Combined with clever water management solutions, such as podium decks, much needed amenity – including roof cafés or small on-site parks for example – can be created. Space can also be made for the planting of large trees to provide shade with the installation of below-ground geocellular units – which can also sit below car parks and playgrounds where water and flooding would ordinarily make these spaces unusable. And interesting green landscapes that treat and reuse rainwater can be created with swales flanked by permeable cycle paths and additional filter strips.

Typically, a good water management design that's considered from the very beginning of a project can deliver significant benefits over those designed as a retrofit solution. However, in some cases, even these scenarios can produce favourable results.

It's pertinent, therefore, to understand as early as possible what water management solutions benefits your project is likely to deliver, and if they could be improved upon. A Blue-Green roof won't help with infiltration, for example, but it can help cool the building using the vegetation as a barrier and benefiting from its evaporative cooling capability. It can also help to attract biodiversity, create amenity space, capture rainwater at source and help with rainwater reuse. All of this, just by installing a geocellular unit podium deck.

Whereas, infiltration can be achieved through many other techniques depending on the location and size of the site needing water treatment – especially in areas at risk of severe weather events. This is where good, intelligent design comes into its own, enabling an understanding where to use the correct green infrastructure/Blue-Green infrastructure solutions for the best outcomes. Swales and ponds, filter strips and permeable pavements, they all play a part – but can also be irrelevant in the wrong situation. That said, in the correct application, these techniques can deliver extremely successful results. And they can be further enhanced with Polypipe products that help slow the velocity of water and reduce its volume, whilst providing storage, attenuation, infiltration and improved water quality benefits.

At a glance; the techniques to help make a difference

Even if a development isn't able to include all techniques, it's good to know that the ones it can include will have the potential to make a positive difference. The Benefits Matrix will help you design your project to include techniques that will benefit your development and, ultimately, help towards making cities more resilient.

	Benefits									
Techniques	Making Space for Water	Surface Water Management	Water Quality	Placemaking	Amenity	Urban Farming	Health & Wellbeing	Biodiversity	Evaporative Cooling	Asset Creation
Blue-Green Roofs	▲	▲		▲	▲	▲	▲	▲	▲	▲
Podium Decks	▲	▲	▲	▲	▲		▲	▲	▲	▲
Trees	▲	▲	▲	▲	▲		▲	▲	▲	▲
Sports Pitches*	▲	▲		▲	▲		▲		▲	▲
Cycle Paths*	▲	▲	▲		▲		▲			▲
Permeable Pavements	▲	▲	▲	▲	▲					▲
Bioretention Systems	▲	▲	▲	▲	▲		▲	▲	▲	▲
Attenuation Storage Tanks	▲	▲	▲							
Infiltration Systems	▲	▲	▲		▲					
Swales	▲	▲	▲	▲	▲			▲	▲	▲
Filter Drains	▲	▲	▲							
Detention Basins	▲	▲	●	▲				▲	▲	
Ponds & Wetlands		▲	▲	▲	▲		▲	▲	▲	▲
Filter Strips		▲	▲					▲	●	

Key:

▲ Can be achieved with Polypipe

● Further benefits e.g. water quality, storage, & control can be achieved by using Polypipe's proprietary systems page 236

* Sports pitches and cycle paths are applications

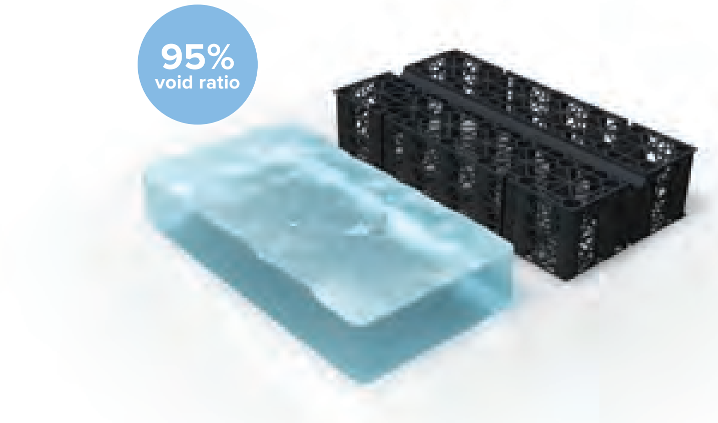
Stormwater Attenuation, Walthamstow Stadium Development

Permavoid: flexible, modular source control drainage systems

Suitable for virtually any project, the Permavoid system meets the demands of current legislation whilst providing developers with an unmatched water management and treatment solution.

It's designed to retain, attenuate, infiltrate and treat water at shallower depths and therefore is ideal for managing stormwater at source. Used with additional products, such as Permavoid Biomat or Permaceptor, it effectively filters and treats contaminates, oil and pathogens from surface water run-off from impervious pavements and infiltrated water from permeable paving. Both products treat the water and improve its quality before discharging it into the ground or local watercourse.

Permavoid's geocellular design makes it extremely strong. Made from recycled polypropylene it is perfect for vehicular hard-standing applications, and because of its shallow profile, the need for deeper excavation can be avoided, along with the risk of chemical contamination, high water tables and hard rock areas.



The Permavoid system key benefits

- Designed and tested for retention, attenuation or infiltration at shallower depths
- Provides effective source control
- Can be installed above a high water table
- Allows water to be spread across a wide area
- Can be used in conjunction with soft SuDS to help 'make space for water'
- Ideal for brownfield or contaminated sites
- Provides treatment to remove silt and hydrocarbon deposits
- Removes the requirement for pumping stations
- Oil interception at source – no need for petrol interceptors
- Can be used in combination with the full range of Polystorm geocellular solutions for deeper applications
- Interlocking raft for rigidity and a high compressive and tensile strength under load
- Suitable for use beneath porous and non-porous surfaces
- Reduction in excavation depth and cost
- No need for trench supports or plant to deliver and remove trench support panels

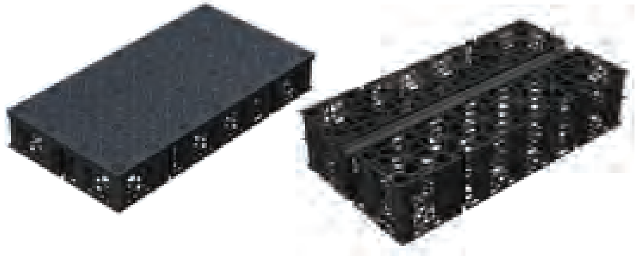
Permavoid system components

Our geocellular sub-base replacement system (Permavoid 85mm and 150mm) locks together to fit any site and is ideal for shallow stormwater attenuation and/or infiltration systems.

Its tensile strength allows for a range of applications including residential and industrial estates, car parks, sports pitches, roofs, basements and pedestrian areas. And, given its high-volume ratio, it can work with our Ridgistorm-XL system to deliver effective large capacity rainwater harvesting.

Permachannel is used to capture surface water run-off from non-permeable and permeable hardstanding areas. It treats the captured water via a weir and baffle component before discharging it to the Permavoid layer below where the water can be attenuated or filtered through Permavoid Biomat geocellular units for reuse.

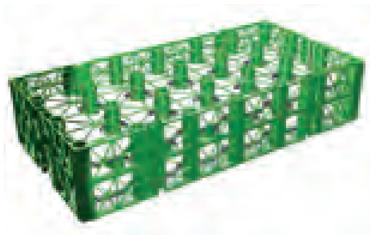
To improve the quality of the captured water, Permavoid Biomat is fitted with a floating oil treatment geosynthetic mat, preventing any excess oils and hydrocarbons entering the storage system. With the same storage, attenuation and harvesting capabilities as standard Permavoid.



Permavoid (85 & 150)

Product codes: PVPP85 & PVPP150

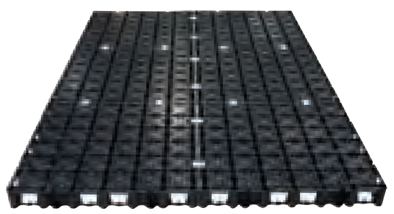
Geocellular sub-base replacement system that locks together to form an interlocking raft of exceptional high compressive and tensile strength.



Permavoid Biomat

Product code: PV150BM

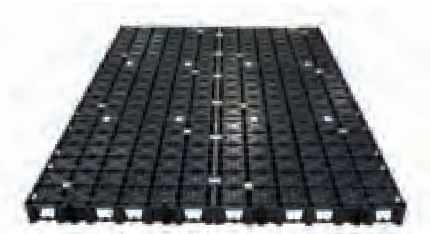
High strength geocellular unit containing a low density, oil treating, geosynthetic floating mat.



Permavoid² 85

Product code: PVPP85RX6

Permavoid² 85 comprises of six pre-connected units and is designed to provide attenuation for shallow non-loaded applications. Ideal for use in the most diverse roof and podium deck applications, alongside hard-landscaping.



Permavoid² 85 Irrigation

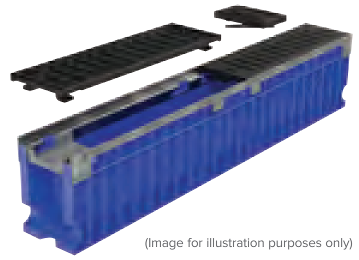
Product code: PVPP85RCX6

Permavoid² Irrigation comprises of six pre-connected units with an integral wicking media and is designed to provide attenuation and irrigation for shallow non-loaded applications. The stored water is carried up through the cell via absorbent capillary action and, in conjunction with Permavoid Permatex Capillary Geotextile, is spread laterally across the surface area. Ideal for use in the most diverse roof and podium deck applications, enabling extensive and intensive greening, alongside hard-landscaping.

Permafoam (85 & 150)

Product codes: PVPP85PF & PVPP150PF

An open celled absorbent phenolic foam incorporated into Permavoid geocellular units for 'on demand' irrigation or check dams.

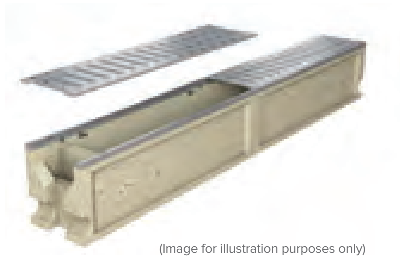


(Image for illustration purposes only)

Permatreat

Product codes: PVTS & PVTEA

Available in two grating options, Permatreat is a versatile, linear treatment system that can provide source control and pollution treatment in a wide variety of locations and applications. The Permatreat channel functions as a combined run-off collection system, whilst intercepting silt and oil from surface water run-off.



(Image for illustration purposes only)

Permachannel

Product code: PV03001

A linear treatment system that combines run-off collection, silt and effluent interception and water treatment functions.

Permaceptor

Product code: PV04002

A combined run-off collection, silt/oil interceptor and treatment system used with road/yard gullies.

Permavoid Rainwater Diffuser Unit

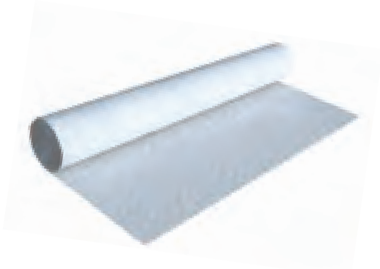
Product code: PV09011

Permavoid units encapsulated with a 2mm mesh fabric diffuse the collected run-off into the surrounding granular sub-base.

Permatex (200 & 300) Geotextiles

Product codes: PTEX200525, PV23010 & PV23011

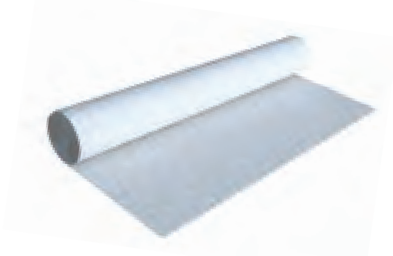
Medium and heavy duty, non-woven, polypropylene, geotextiles designed to provide protection, separation and filtration.



Permatex Capillary Geotextile

Product codes: PV23008 & PV23009

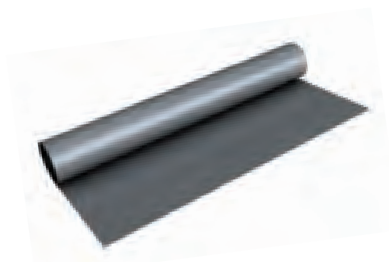
A heavy duty, non-woven geotextile formulated to provide passive irrigation to soft and landscaped areas.



Permafilter Geotextile

Product code: PV23002

A non-woven, dimpled, needle-punched geotextile designed for hydrocarbon pollution treatment.



Geomembrane

Product codes: PV13007, PV13008, PV13009, PV130010 & PV130011

An impermeable membrane for encapsulating Permavoid structures to form watertight tanks.

Permaties

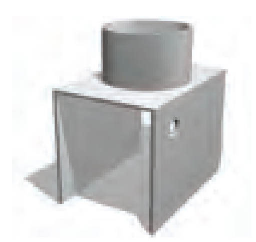
Product code: PVCLIP

Fully interlocking tapered tie connections to securely link Permavoid cells together horizontally in a single structure and to transfer tensile loads.

Shear Connector

Product code: PVSC

Securely links multiple layers of Permavoid together in a single structure.



Permavoid Connectors

A range of Spigot and Saddle Connectors allowing piped connection to the Permavoid structure.

Podium Deck Rainwater Pipe (RWP) Chamber

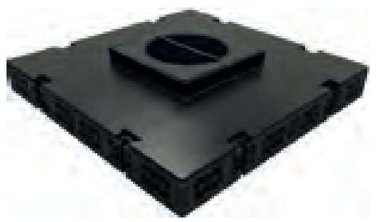
Product code: PV0D01402

The RWP chamber is designed for use in shallow Permavoid podium deck constructions; the Podium Deck RWP Chamber collects rainwater from the inlet pipe, filters the water through the perforated walls and disperses it into the surrounding Permavoid storage system.

Podium Deck Roof Outlet

Product code: PV0D01302

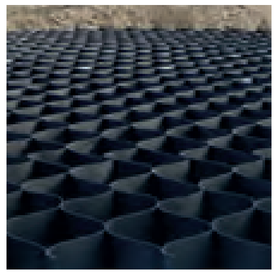
The Podium Deck Roof Outlet Chamber is set within the Permavoid, providing a quick and easy connection to surrounding Permavoid. The chamber allows for easy access to an existing roof outlet for routine maintenance.



Podium Deck Gully

Product code: PV0D01201

The podium deck gully creates a point in the Permavoid system for surface water from paved surfaces to enter the Permavoid system for storage, conveyance and later reuse.



InfraWeb GS

Product codes: GS10, GS15, GS20, GS25, GS30, GS35, GS40

InfraWeb GS is a 3 dimensional cellular confinement system used to provide load support, erosion control, channel protection and for the construction of earth retaining structures.

InfraWeb TRP

Product codes: IW5035, IW7535, IW10035, IW15035 & IW20035

InfraWeb TRP (Tree Root Protection) is a 3 dimensional cellular confinement system used to construct vehicular access roads, parking areas etc around the Root Protection Area of existing trees.

GS Pro

Product codes: PP35GSPB & PP35GSPG

GS Pro Plastic Paving Panels are manufactured from high-quality polypropylene. The GS Pro has double cell walls, to provide extra strength, and also has a unique panel connection system which limits both horizontal and vertical expansion.

Treebox HP

The TreeBox HP system has a load capacity of 60 tonnes and is suitable for all types of load bearing applications – allowing for inner-city tree planting and providing the perfect growing environment for tree roots without damaging the surrounding surface.

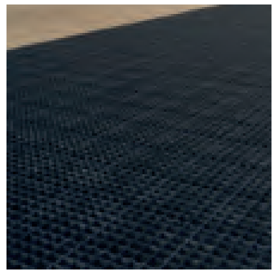
Gravel Pro

Product codes: PP40GPW & PP40GPB

Gravel Pro offers plastic permeable paving solutions to cover a wide range of applications from simple footpaths and temporary car parking to fully engineered grass and gravel paving systems for heavy goods vehicle parking areas.

ArborRaft

The ArborRaft system prevents damage to the root structure from vertical pressures by absorbing imposed loads placed upon it. This permits the root structure of new and existing trees to grow in a healthy environment.



FlowBlock

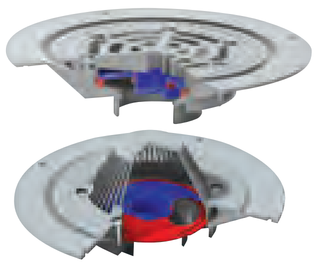
Product codes: PP75FBB & PP75FBG

FlowBlock is a high strength, modular permeable paving and grass protection system. The 500mm x 500mm units are manufactured 75mm thick for heavy duty applications such as HGV access and intensively trafficked areas.

SlimBlock

Product codes: PP50SBB & PP50SBG

SlimBlock is a high strength modular paving system manufactured from recycled plastic. The 500mm x 500mm units can be infilled with grass or with gravel depending upon the aesthetic requirements of the site.



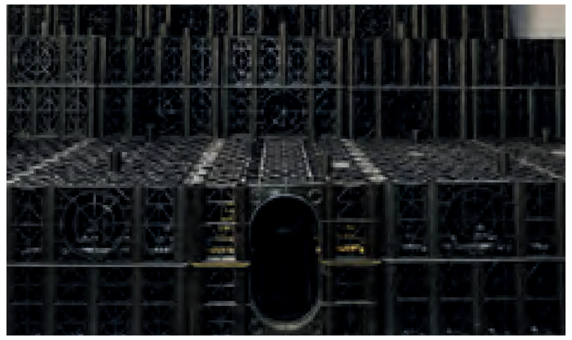
Terrain Reduced Flow Outlet Restrictor

Reduced Flow Rainwater Outlets are from Polypipe's Terrain range of PVCu rainwater outlets fitted with a variable flow control orifice plate. The range includes flat, domed, vented and inverted roof outlets, which are designed for use with Permavoid rainwater attenuation systems for roofs and podiums.

Bespoke sustainable drainage systems (SuDS), David Wilson Homes

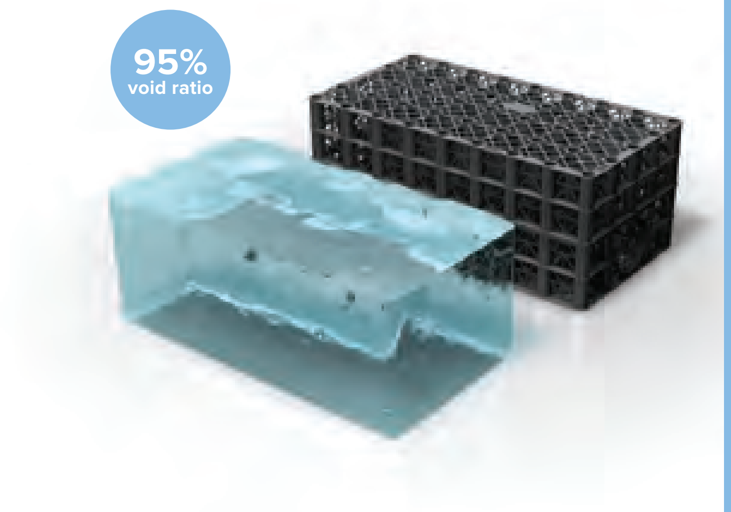
Polystorm: strength and flexibility for deeper applications

The Polystorm system can be installed at varying depths and is able to accommodate a wide range of non-traffic and traffic loadings and making space for water.



Thanks to its vertical compressive strength capabilities the Polystorm system can handle a wide range of loadings from 20 up to 83 tonnes per square metre – ideal for pedestrianised areas to large HGV parks.

And with a 95% void ratio, its capability to store maximum volumes of water is matched only by its sustainability credentials – reducing excavation and disposal costs, and being 100% recyclable at the end of its useful design life; of up to 50 years.*

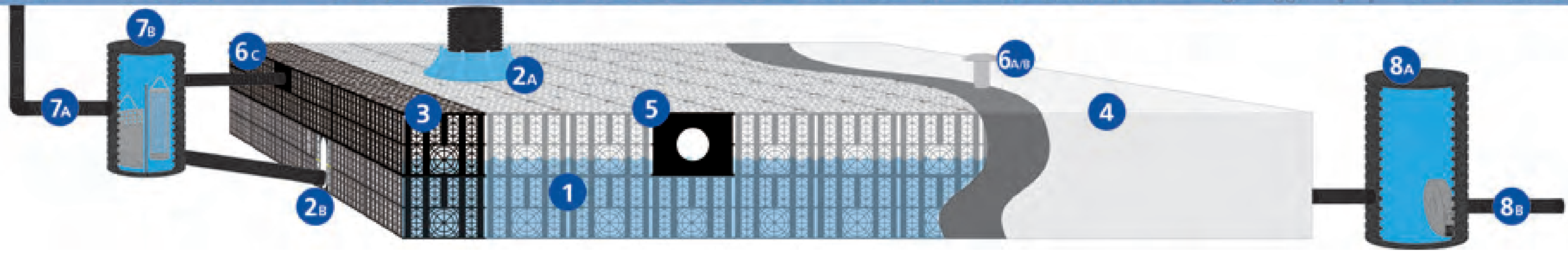


Polystorm system key benefits

- 95% void ratio providing greater water storage capacity and reduced excavation and disposal costs
- BBA approved for Polystorm Lite, Polystorm-R and Polystorm. BBA pending for Polystorm Xtra
- Modular units allow flexibility of shape, making it ideal for shallow excavation systems, narrow strips or for use in restricted areas
- Light in weight yet robust, affording excellent Health and Safety and installation benefits
- Unique rounded corners make it easy to handle and reduce likelihood of punctures to membranes
- 100% recyclable at the end of its useful life
- Spans from 20 tonnes up to a maximum of 83 tonnes per square metre vertical load bearing capacity
- The range can be designed for non-trafficked, trafficked or heavily trafficked applications
- Suitable for retention, attenuation and infiltration systems
- Up to 50-year design life*
- Polystorm modular cells manufactured from polypropylene
- Polystorm Access manufactured from Polyethylene

* Within certain applications and conditions

An 8 step guide to a total Polystorm system



1 Select modular cell

Polystorm Lite

Product code: PSM2

Vertical compressive strength: 20 tonne/m²

Landscaped/pedestrian

Polystorm Lite has been specifically designed for non-trafficked, landscaped and pedestrian applications.

Polystorm Xtra

Product code: PSM3

Vertical Compressive strength:83 tonne/m²

Heavy trafficked or reduced cover

Designed for use in heavily trafficked areas for shallow, non sub-base applications where reduced cover is required.

Polystorm-R

Product code: PSM1A

Vertical compressive strength: 61 tonne/m²

Trafficked

The standard Polystorm cell for trafficked and loaded applications at greater depths has the added benefits of a higher recycled material content.

Polystorm Deep

Product code: PSM5

Vertical compressive strength: 61 tonne/m²

Heavy trafficked or reduced cover

Polystorm Deep has been designed for use in trafficked applications such as lorry parks and industrial access roads. It can be buried deeper than any other Polystorm cell and can be value engineered as part of a hybrid system.

Polystorm

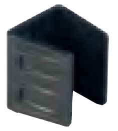
Product code: PSM1

Vertical compressive strength: 44 tonne/m²

Trafficked

The Polystorm cell, made of virgin material, is ideally suited for trafficked and loaded applications at greater depths.

Connection accessories



- Clips
  Product code: PSMCLIP

- Shear Connectors
  Product code: PSMSC

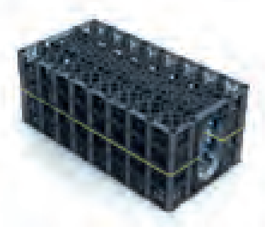
- Brick Bond Connectors
  Product code: PSMBBSC

Note: Clips and shear connectors are supplied with all Polystorm units.

2 Select access if maintenance and inspection is required

2A Polystorm Access

Polystorm Access provides a 1m x 0.5m vertical shaft within a Polystorm geocellular structure to enable surface access for remote camera inspection and maintenance activities such as flushing and rodding.



2B Polystorm Inspect – Product code: PSM4

Polystorm Inspect provides a tunnel along the length of a fully installed Polystorm system to enable horizontal access for inspection and maintenance. It can also be used in conjunction with Polystorm Access.

3 Select if treatment is required

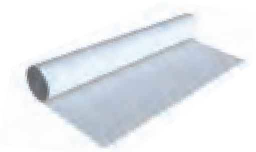
Permavoid Medium Duty with Biomat – Product code: PSM1BM

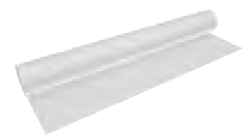
Comprising of a high strength, low density, oil treating geosynthetic floating mat for use with the Polystorm range of modular geocellular units.

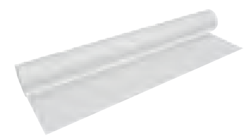
For multi-stage oil interception the Permavoid Medium Duty with Biomat can be used in conjunction with Permatreat or Permachannel (linear treatment) or a pre-fabricated RIDGISTORMSeparate-X4 Chamber (point treatment).

8 step guide continued...

4 Select wrap







Geomembrane for retention & attenuation

An impermeable membrane for encapsulating geocellular structures to form watertight tanks. This is then wrapped in Permatex 300 to protect the geomembrane from puncture.

Permatex 300 for protection

A non-woven protective geotextile used externally to a geomembrane for added protection.

Polystorm Soakaway Geotextiles for Infiltration

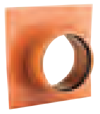
Available as standard (PVTS1000) or heavy duty (PVTS2000), non-woven infiltration geotextiles for encapsulating geocellular structures to form soakaway tanks.

Permafilter Geotextile for treatment and infiltration

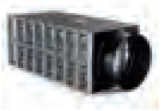
This geotextile has been specifically designed to remove hydrocarbon pollution, treating the captured water before infiltrating it into the ground.

5 Pipe Connections

A flange adaptor is attached at both the inlet and outlet points to allow water to enter and exit the tank via connecting pipes.



Flange Adaptor to EN1401



Polystorm cell with Ridgidrain Flange Connection

- Polystorm cells with Flange Connections to Ridgidrain drainage pipes: PSMCRD225 (225mm), PSMCRD300 (300mm)
- Polystorm Inspect cells with Flange Connections to Ridgidrain drainage pipes: PSM4CRD225 (225mm), PSMCRD300 (300mm)
- Flange Adaptor to EN1401: PSMFA110 (110mm), PSMFA160 (160mm)
- Flange Adaptor to Ridgidrain: PSMFA150 (150mm), PSMFA225 (225mm), PSMFA300 (300mm), PSMFA375 (375mm), PSMFA400 (400mm), PSMFA450 (450mm), PSMFA500 (500mm), PSMFA600 (600mm)

6 Venting

Every attenuation tank requires at least one vent to maximise hydraulic performance and reduce stress on encapsulating geomembranes. This can be done by installing either a Vent Cowl or a connection pipe to vent air directly into an upstream chamber.

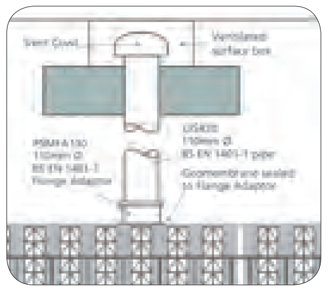
6A Vent Cowl

Product code: SCV40

To vent air above ground.

6B BS EN1401-1 pipe

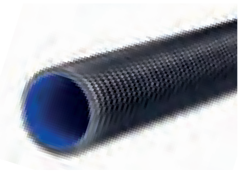
Product code: UG430



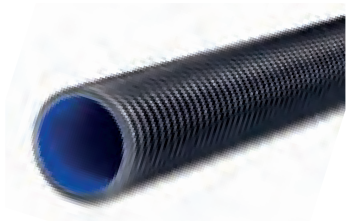
6C 150mm Ridgidrain pipe

Product code: RD150X6PE

For ventilation into the upstream chamber.



7 Associated upstream products



7A Ridgidrain

Ridgidrain can be utilised within a Polystorm system by conveying captured surface water to the attenuation or infiltration tank.

7B Polystorm Catchpits & RIDGISTORMSeparate Chambers

Polystorm Catchpits and RIDGISTORMSeparate Chambers are easily maintainable and prevent the ingress of debris, silt, organic and other particles into the Polystorm structure, extending its useful life.

Polystorm Catchpits

A pre-fabricated 600mm diameter catchpit with three inlet/outlet sizes available in 150mm, 225mm and 300mm.

Silt Traps

320 - 460mm Silt traps are available from the RIDGISTORMSeparate Silt Traps range.

Mini & Basic Catchpits

450 - 3000mm diameter bespoke catchpits are available from the RIDGISTORMSeparate range.

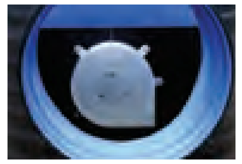
Advanced Catchpits

In addition to silt traps and catchpits, we also offer RIDGISTORMSeparate Advanced Catchpits with additional treatment features.

8 Associated downstream products

8A RIDGISTORMCheck

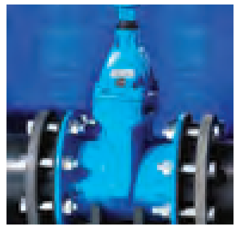
A choice of Vortex or Orifice Plate Flow Control Chambers for precise control of site discharge rates.



RIDGISTORMControl

Pre-fabricated structured wall chambers which feature 'in-line' system components such as penstocks, gate valves or flap valves to control system flows and facilitate maintenance.

Penstock

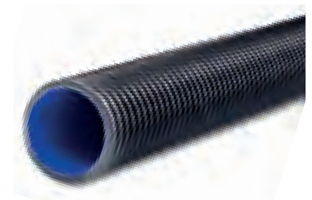


Gate valve

Flap valve

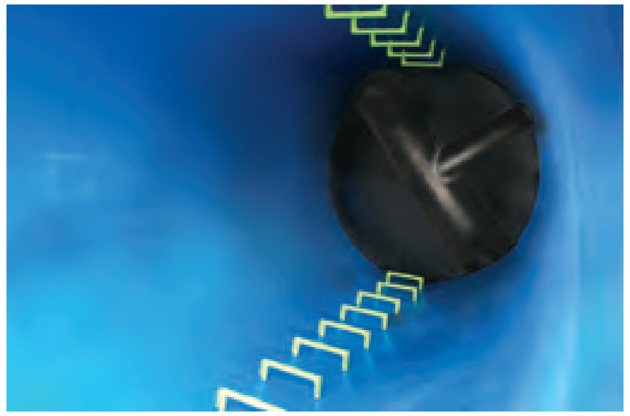
8B Ridgidrain

Ridgidrain can be utilised to drain away stored water from a Polystorm attenuation tank.



Ridgistorm-XL Component Chambers

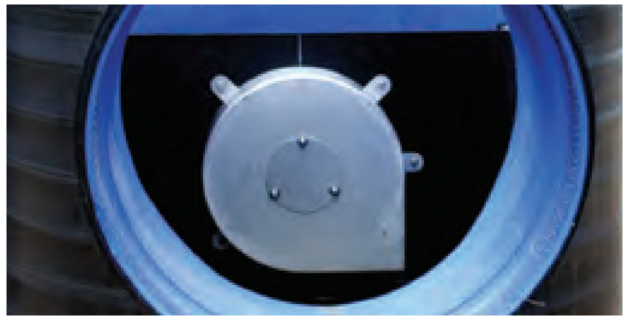
We constantly work to find the most efficient and innovative solutions to help the construction industry deliver the highest quality, cost-effective and sustainable water management solutions. Our pre-fabricated products do just that – and are engineered to fit our range of pipe systems precisely whilst matching specific project requirements, delivered to site ready to install.



RIDGISTORMAccess Manholes

Engineered for use in stormwater, foul and combined sewer applications to enable access to the pipework system for inspection and maintenance.

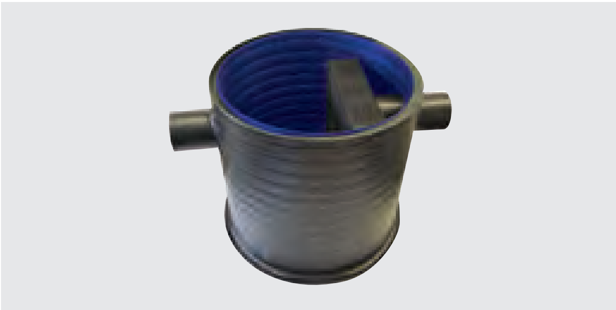
They reduce the need for direct access into the pipeline and minimise operational Health and Safety risks with the pre-fabrication of optional Safety Chain Assembly and Guardrail Assembly. RIDGISTORMAccess Manholes are utilised where pipe runs change direction, combine, change invert level, diameter or pipe material.



RIDGISTORMCheck Vortex Flow Control Chamber

Allows for precise control of site discharge rates and provides an industry recognised flow attenuation solution.

They are site specific and engineered to suit a range of stormwater attenuation systems providing a hydraulically efficient means of flow regulation that does not use moving parts or require power to operate.



RIDGISTORMCheck Orifice Plate Flow Control Chamber

Incorporating an integral orifice plate flow control with an optional, fully-removable Permavoid filter unit wrapped in a 2mm polyethylene mesh to provide filtration and ease of maintenance.

They allow for precise control of discharge rates and provide an industry recognised flow attenuation system, in a simple and cost-effective design.

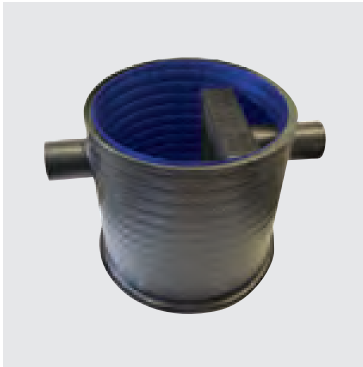
Flap Valve

Penstock

RIDGISTORMControl Chambers

Our pre-fabricated RIDGISTORMControl Chambers incorporate a range of devices to limit or isolate flows within surface water, sewer and combined sewer systems.

Typical valves include: Gate Valves (used to permit or prevent the flow of water and can isolate drainage sections), Flap Valves (non-return valves to prevent backflow upstream) and Penstocks (consist of a gate which can isolate or control water flow).



RIDGISTORMSeparate Silt Traps

Located upstream of retention, attenuation and infiltration systems.

RIDGISTORMSeparate Silt Traps capture and retain silt and separate out other particles by encouraging settlement in the units sump, preventing ingress into sustainable drainage systems (SuDS).

RIDGISTORMSeparate Mini Basic Catchpits

Ideal for stormwater systems and land drainage applications, they are the simplest and most cost-effective way of separating out silt and debris, providing an easily maintainable drainage system.

They help to protect the downstream drainage system and local environment.

RIDGISTORMSeparate Advanced Catchpits

Incorporating both a sump and removable filter unit on the chamber outlet to capture silt and debris.

The filter unit is easily removed for maintenance purposes.

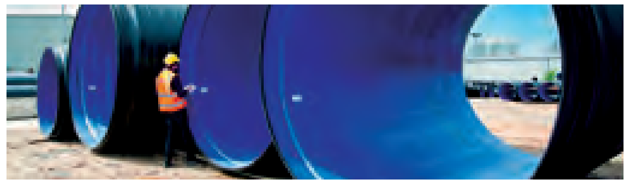
RIDGISTORMSeparate-X4

Offering advanced 4-stage filtration of surface water run-off, providing high levels of solid and dissolved phase contaminant removal, including hydrocarbons and heavy metals.

The RIDGISTORMSeparate-X4 stormwater treatment system utilises consecutive processes to provide consistent levels of protection for the downstream elements of the drainage system and local environment.

Additional engineered systems

The demand for comprehensive water management and climate solutions has never been more pressing. And like Permavoid, Polystorm and Ridgistorm-XL, our additional engineered products and systems have been designed to help you deliver a more successful project to include Green Urbanisation.

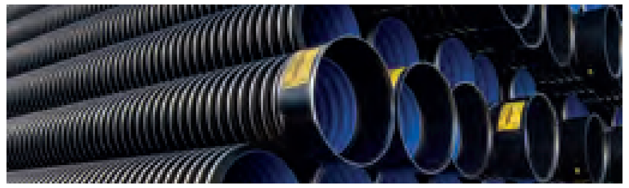


Ridgistorm-XL

An engineered, large diameter pipe solution for surface water, foul water and combined sewer applications.

Rainstream

Rainwater reuse systems for both commercial and residential applications.



Ridgidrain

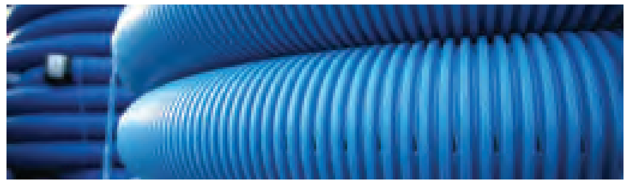
A high strength HDPE surface water drainage piping system, used for surface and sub-surface drainage applications.

Polysewer

A PVCu sewer pipe system available in sizes 150mm-300mm.

Ridgisewer

Highly durable and versatile, the Ridgisewer sewer pipe system range is engineered from long-life, durable Polypropylene in 400mm-600mm diameters and Polyethylene in the larger 750mm and 900mm diameter pipes.



Landcoil

A land drainage system for the management of excess land water.

Cable protection

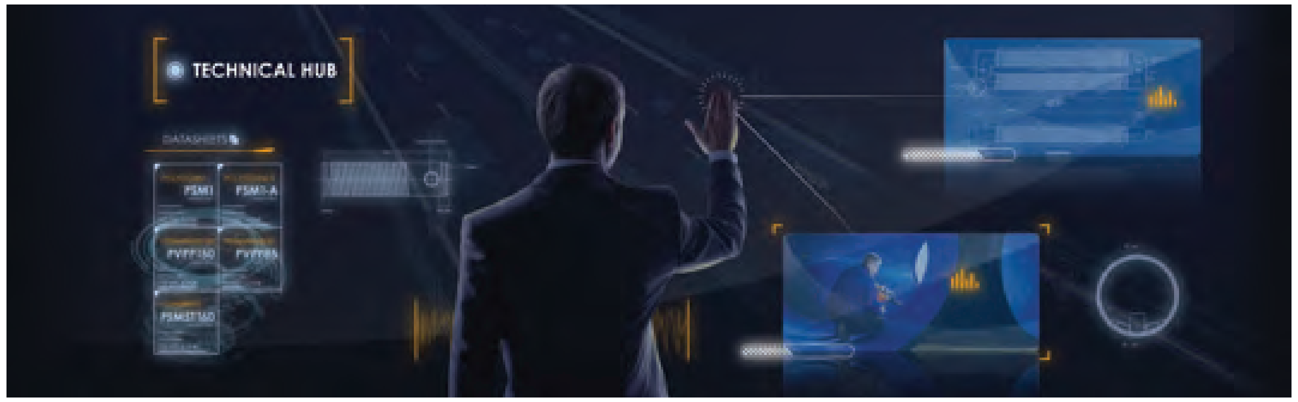
Protects cables and conduits carrying power, motorway communications, lighting and utilities in almost every application.

Ventilation Systems

Nuaire and Domus mechanical ventilation with heat recovery systems for sustainable climate management solutions.

Technical Hub

Our Technical Hub is the platform from which to explore technical product specification details in one easy-access location – providing the information you need to create the best system possible. And we'll help you with your design, working with you to find the right solutions.



Water management innovation

You can now access CAD Standard Details, Datasheets and Technical Manuals for all our products – allowing you to design the most efficient water management solutions, drainage solutions and cable management solutions for your project.

The Technical Hub provides you with unlimited access to a wide variety of support materials, but we also provide additional support tools including datasheets, technical manuals, technical bulletins, DWG files and specification clauses that can be freely and easily downloaded. You can also view previous case studies of Polypipe products in action and how the systems have been manufactured to meet the project's exact requirements – including everything from infrastructure, residential and commercial projects utilising engineered SuDS to schemes that include Green Urbanisation and make space for water.

The materials you need to succeed

From legislation, product design, approvals and certification documents to installation guides and Health and Safety compliance – we have the topics, so you have the know-how.

- Standard details
- Datasheets
- Technical manuals
- Case studies
- Structural design
- Hydraulic performance
- Chemical resistance
- Applications
- Installation guidance
- Maintenance
- Structural performance
- Pollution control
- Minimum cover depths

For more information, visit
polypipe.com/civils-technical-hub

Polypipe project and technical support

To ensure you deliver the best and most sustainable project possible, we have a team of specialists to support you. Not just help with design and product capability, but with technical know-how and a scaleability to provide a seamless operation for from start to finish.

Moving forward

Even in these challenging times; climate change, population growth and the spread of necessary urbanisation, we can still make a difference. Helping to mitigate the effects these challenges pose through clever water management solutions. Introducing Green Urbanisation and biophilic design, ensuring our cities become more resilient whilst providing people with a healthier, more engaging environment. And bringing new innovations, from plumbing and drainage to ventilation and fabrication.

It's a time, particularly with new technologies, that we are able to continually evolve our products and systems to deliver alternative drainage strategies, those based on nature, which control, store, manage and reuse rainwater, but also protect and enhance the urban environment whilst introducing new and important amenity and places where people want to be.

Remarkable systems, for example, that use vegetation such as plants, grasses, trees and shrubs, to manage water through natural drainage simply by using soil and root systems together with engineered SuDS. Our InfraGreen solutions are able to introduce larger trees into a built environment as part of an urban drainage system, creating almost instant Green Urbanisation and the multifunctional benefits that come with it; attracting biodiversity, trapping harmful pollutants, providing shade and reducing temperatures through evaporative cooling.

Each product, every system will play a part in making construction better, simpler, more dynamic. Technological advancement and enhancements will provide the opportunities to design more astutely; already we're working with Virtual Reality and BIM modelling to achieve these goals – whilst working with you to ensure your projects are designed for the future.

And we'll never stop. We'll continue to invest in engineered water management solutions that bring whole life value to your projects, that include biophilic design and SuDS to create Blue-Green Urbanisation, providing people and wildlife with an environment in which to thrive – and achieved with only the most sustainable, beneficial, energy-efficient and cost-effective products; engineered from the most practical, recycled and recylable materials.

In many ways, the answers to a more resilient future have always been there. In the trees we look up to, the plants we enjoy surrounding us and the natural rivers and countryside we connect with.

It may seem bullish to say we've found a way to help our cities become better places, through creating systems based on nature. But in reality, it's nature that finds a way.

Actions and applications: The technical detail

As the natural landscape becomes ever more diminished by expansive urban development, the natural water cycle has become equally impeded – reducing important natural infiltration systems.

To help address these challenges, Polypipe's engineered SuDS have been designed to work as an effective solution on their own or together with soft SuDS – introducing effective, controlled retention, attenuation and infiltration where rain falls or as close to the source as possible.

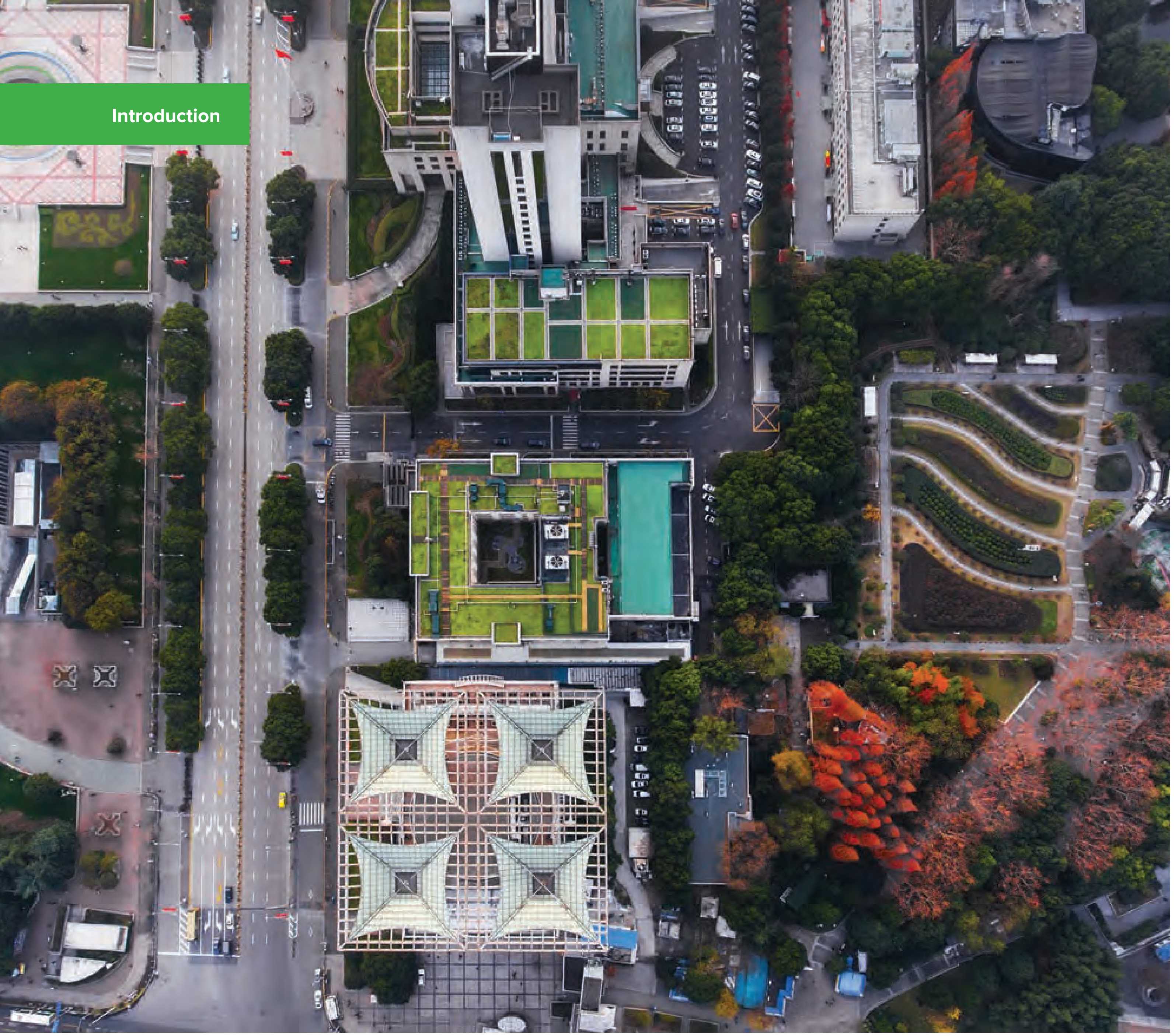
SuDS can be used anywhere there's surface water run-off. Polypipe water management solutions, therefore, integrate with soft SuDS such as swales, ditches and ponds to manage infiltration, volume and velocity. Hard surface design can include infiltration and water interception via geocellular units beneath the pavement. Natural infiltration systems can be enhanced by the design and installation of silt traps to facilitate maintenance and extend the life of the infiltration drainage element.

3

The following technical information will demonstrate how by adopting the 'four pillars' early in your project, either as standalone systems or a combination of SuDS components within a site, will help to ensure surface water run-off is both managed and utilised as a resource with many benefits.

P+ This symbol indicates a product or system unique to Polypipe which can enhance or add value to the SuDS system or technique.

Section 3 - Contents



Solutions for every space

CIRIA's 'four pillars', water quantity, amenity and biodiversity, shows how good SuDS design can maximise opportunities and benefits using surface water management.

The 'pillars' set out to ensure that systems are in place to store water, filter water for quality and manage it to help create amenity and attract wildlife. And where space is limited, SuDS can be applied to deliver rooftop gardens and podiums, as well as near-surface or below-ground solutions.

Blue-Green roofs can be used to reduce surface water run-off. Planted soil surfaces provide opportunities to increase biodiversity, as well as lowering ambient temperatures and promote community wellbeing, and with the introduction of rooftop podium decks, clever and exciting high-level amenity can be created whilst incorporating sub-deck water storage and attenuation for gravity water solutions.

Restoring the balance with SuDS

The natural water cycle maintains a balance of water within the environment through a process of evaporation, transpiration, precipitation, infiltration, ground and surface water flows.

Altered water cycles put pressure on natural landscapes and, in densely developed areas, the resulting increased volume and velocity of surface water can cause increased flooding, erosion and subsequent degradation of vegetation and biodiversity. The SuDS approach aims to mimic the natural water cycle as the baseline against which system performance is evaluated.

At a glance; the techniques to help make a difference

Even if a development isn't able to include all techniques, it's good to know that the ones it can include will have the potential to make a positive difference. The Benefits Matrix will help you design your project to include techniques that will benefit your development and, ultimately, help towards making cities more resilient.

Techniques	Making Space for Water	Surface Water Management	Water Quality	Placemaking	Amenity	Urban Farming	Health & Wellbeing	Biodiversity	Evaporative Cooling	Asset Creation
Blue-Green Roofs	▲	▲		▲	▲	▲	▲	▲	▲	▲
Podium Decks	▲	▲	▲	▲	▲		▲	▲	▲	▲
Trees	▲	▲	▲	▲	▲		▲	▲	▲	▲
Sports Pitches*	▲	▲		▲	▲		▲		▲	▲
Cycle Paths*	▲	▲	▲		▲		▲			▲
Permeable Pavements	▲	▲	▲	▲	▲					▲
Bioretention Systems	▲	▲	▲	▲	▲		▲	▲	▲	▲
Attenuation Storage Tanks	▲	▲	▲							
Infiltration Systems	▲	▲	▲		▲					
Swales	▲	▲	▲	▲	▲			▲	▲	▲
Filter Drains	▲	▲	▲							
Detention Basins	▲	▲	●	▲				▲	▲	
Ponds & Wetlands		▲	▲	▲	▲		▲	▲	▲	▲
Filter Strips		▲	▲					▲	●	

Key:
▲ Can be achieved with Polypipe
● Further benefits e.g. water quality, storage, & control can be achieved by using Polypipe's proprietary systems page 236

* Sports pitches and cycle paths are applications

3.1 Blue-Green Roofs

The Polypipe Blue-Green roof system can be installed to provide areas of living vegetation at roof level. By providing source control for water, which would otherwise run-off to downstream attenuation systems or sewers, we are able to capture, treat and store water, to be used for the purpose of irrigation to areas of vegetation.

Such a system can be considered as a part of the overall SuDS Management Train for the building on which it is installed.

Multifunctional benefits of Blue-Green roofs

MAKING SPACE FOR WATER
Enhanced storage capacity by integrating geocellular or pipe solutions.

SURFACE WATER MANAGEMENT
Source level flow control adds water treatment.

PLACEMAKING
Creating attractive green spaces in urban areas that wouldn't usually be available.

EVAPORATIVE COOLING
The inclusion of rain gardens within developments can provide cooling via return of moisture to the air through vegetation/evapotranspiration potentially reducing a building's energy requirements. Can also reflect sunlight.

AMENITY
Enables easy integration into various designs, provides aesthetics, increase in vegetation, adds water treatment.

URBAN FARMING
Utilising passive irrigation, crops can be grown at roof level.

HEALTH & WELLBEING
Rain gardens that are accessible or overlooked can increase mental wellbeing.

BIODIVERSITY
Quality habitat for wildlife and plants, which can be added to both new and existing urban areas.

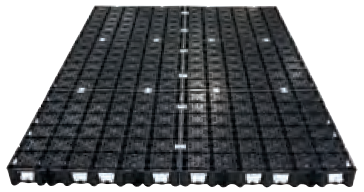
ASSET CREATION
Addition of gardens/green spaces can increase the aesthetic look of an area adding value to the property.

Dual purpose enhancement

Our system has a geotechnical cell at its heart, allowing us to both store water for irrigation and attenuate and discharge water at a known flow rate for particular storm events.

One system


Permavoid at roof level


Permavoid² 85 panel


Permavoid 85mm

The Permavoid² 85 and the Permavoid 85mm are compatible with each other and form a part of all roof build-up types – extensive, intensive and bio-diverse.

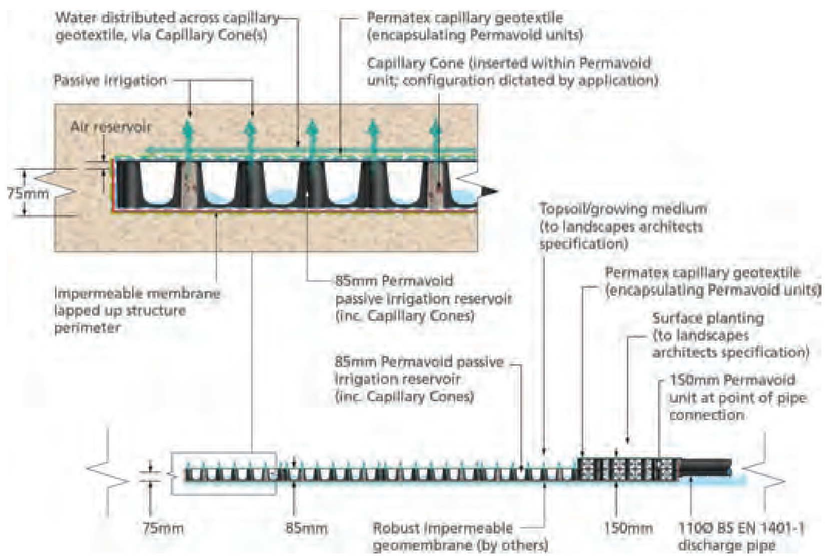
Passive irrigation – capillary action enhancement

The Polypipe Blue-Green roof system provides irrigation to the vegetation via its passive irrigation system where water is delivered to the soil substrate, from below, maintaining an optimum moisture level within the substrate.

Through the use of the patented Capillary Cone installed into either the Permavoid² 85 and Permavoid 85mm unit, water is lifted through the cell, into the capillary geotextile, up into the growing medium and directly into the plant root areas. This water is used as part of the photosynthesis process and would eventually evaporate out of the plant and into the atmosphere.

The benefit of irrigating in this way is that the plant only uses the water it requires – none is wasted. The alternative is to irrigate from above. In this instance some of the water is evaporated before being consumed by the vegetation and some of the water that lands on the ground surface would also evaporate. This effect is increased during hot/dry periods with a high quantity of water evaporating prior to the plant processing it.

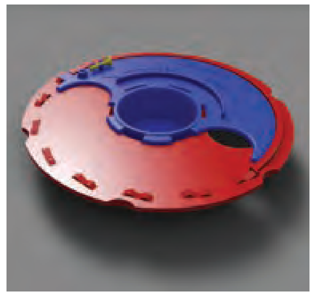
The Polypipe Blue-Green roof is typically designed to store a volume of water at roof level, specifically for the use of irrigation of vegetation. The volume of water depends on many factors, not least the demand imposed by the planters for irrigation water. It should be noted that although the Permavoid effective storage depth is up to 85mm, in reality it's unlikely there'd be no more than 15 to 25mm of water stored for most Blue-Green roof applications.



3.1.1 Controls

The Polypipe Blue-Green roof system can be linked to control and monitoring systems allowing it to act as a stand-alone system or link to other downstream water management systems – such as a capture and reuse storage tank. The captured water can then be used for irrigation purposes, i.e. fed back from the tank to the Permavoid cell area during dry periods and utilising Capillary Cones to draw the water upwards to the growing medium.

Our control systems can monitor water levels within the Permavoid cell as well as the moisture content of the soils supporting vegetation growth. As a result, we can develop a site specific control philosophy to ensure that water is always available to the capillary irrigation system. Alternatively a secondary sprayed or drip irrigation system can be linked to the same monitoring sensors to provide above-the-surface irrigation. This may be required for intensive roof spaces, particularly during the period of establishment.

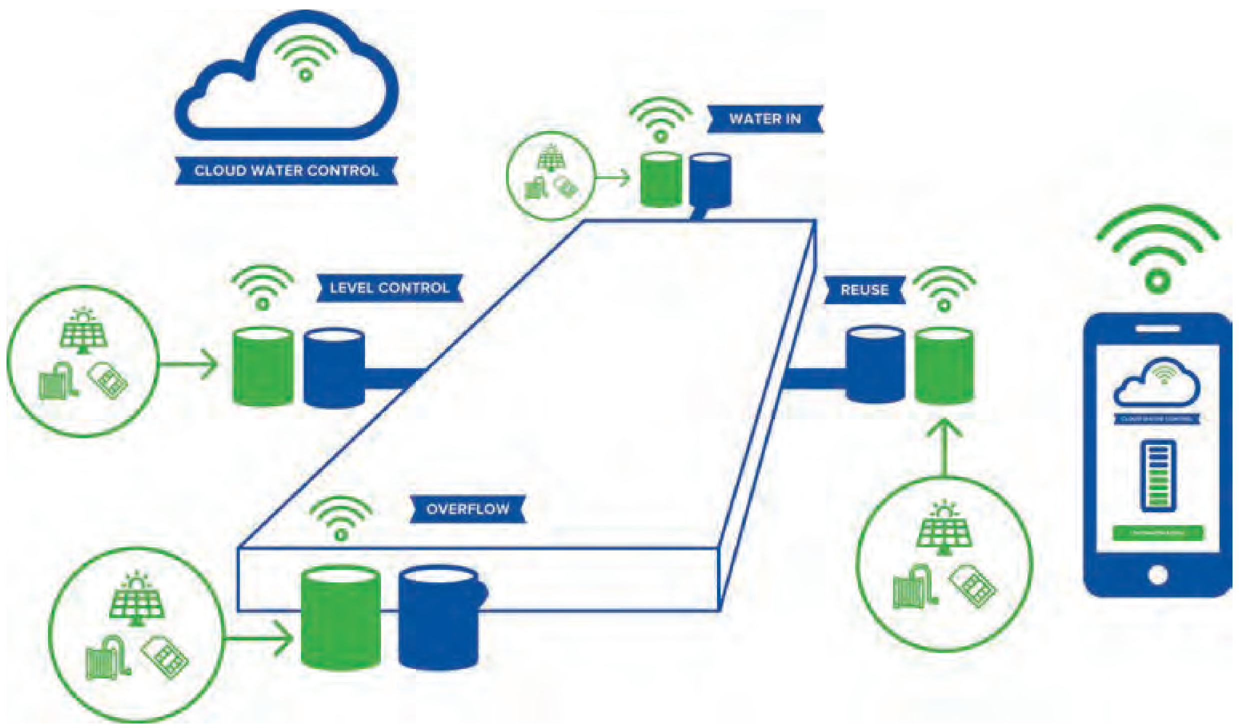


Fabrication

We offer fabricated system components to complete the offer such as roof outlet inspection chambers, parapet rainwater outlets and many other fabricated components required at roof level.

Complete system enhancement

The Polypipe Group can offer the complete system following SuDS Management Train principles, from Source Control at roof level to deep dig attenuation systems and surface water run-off treatment. In addition, Polypipe can provide in-building and underground drainage ranges, pressure pipe systems and control systems that link the various elements of the SuDS Management Train.



There are three main generic types of vegetation that the Polypipe Blue-Green roof system can support – an **extensive roof**, an **intensive roof** and a **bio-diverse roof**. The system can also be installed over the three main roof construction types seen in the UK – a **cold roof**, a **warm roof** and an **inverted roof**.

3.1.2 Blue-Green vegetation types

For all vegetation types the Polypipe Blue-Green roof system provides irrigation water from below the substrate via capillary action. The Permavoid cell holds the water intended for irrigation, with integrated Capillary Cones lifting the water via capillary action to a capillary geotextile layer.

The capillary geotextile layer, laid directly above the Permavoid cell, distributes the water lifted through the capillary cone over a wider area, allowing an even moisture content to be maintained in the soil, thereby making it easier for plant roots to take up water.

3.1.2.1 Extensive roof vegetation

Typically a 20-150mm growing medium, planted with hardy, slow growing, drought-tolerant and low maintenance plants. The systems are lighter in weight and lower in cost to maintain. Ideal for retro-fit due to their lighter weight per square metre.

3.1.2.2 Bio-diverse roof vegetation

This type of roof is specifically designed to replace, as close as possible, the planted environment that existed prior to construction. Therefore it is probable that the build-ups will accommodate elements of both the extensive roof and intensive roof.

3.1.2.3 Intensive roof vegetation

The Blue-Green roof passive irrigation system allows a soil substrate of up to 600mm to provide complex landscaped environments with high amenity and bio-diversity benefits. The roof should be designed to accommodate the higher imposed loads associated with this roof type. A range of plant types can be used including grasses, flowers, shrubs and, in certain instances, trees. This roof type requires a high level of maintenance and for this reason they are generally designed to be easily accessible.

3.1.3 Build-up over roof types

There are three main forms of roof construction used in the UK for areas where source control is installed. The components used in our build-up are similar for each type and a brief introduction is given below.

Protection layer

A protective geotextile fabric, laid over the roof waterproof membrane to protect the membrane from damage.

Waterproof membrane

Supplementary to the roof waterproof membrane, the separate waterproof membrane is used to tank the Permavoid cells. It allows separate tanks to be formed over the roof waterproof membrane so that different use and build-up areas can be formulated.

Permavoid² 85 geocellular unit

An 85mm void former with a high compressive strength which, when fixed together, forms a structural raft on to which the growing substrate can be built up.

Permavoid² 85 geocellular unit with passive capillary irrigation cones

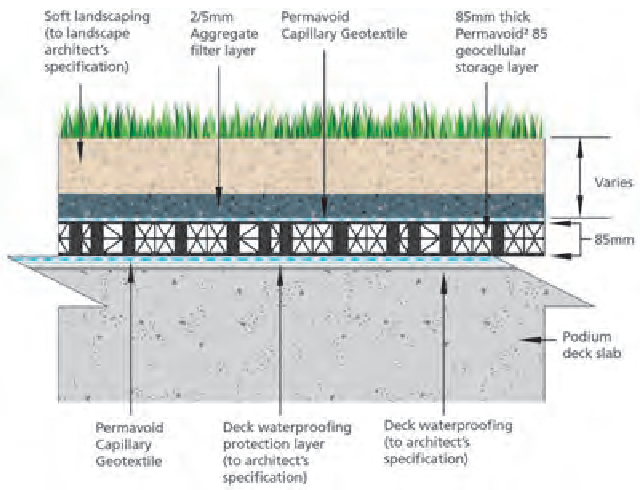
An 85mm void former with a high compressive strength with integrated Capillary Cones. The number of cones is dependant on the water demand requirement of the planters. When fixed together, it forms a structural raft on to which the growing substrate can be built up, with the Capillary Cones delivering water via capillary action.

Capillary geotextile/filter layer/root barrier

A special geotextile fabric designed to distribute the water that is lifted through the Permavoid cell via capillary action across a large area of substrate. It is installed between the soil substrate and the Permavoid cell and also acts as a filtration layer and root barrier.

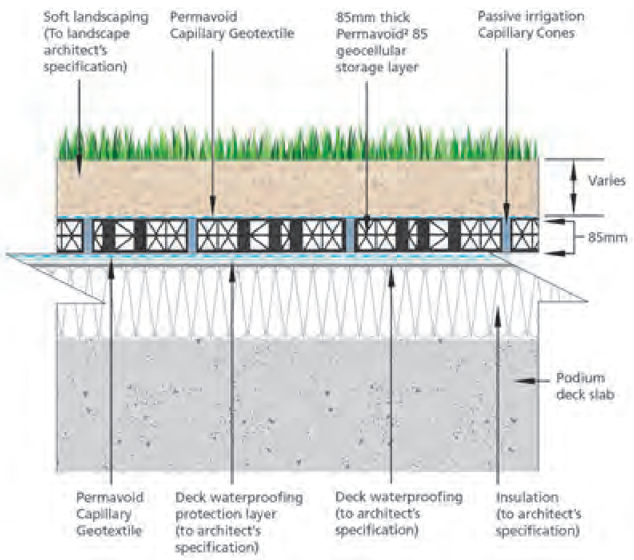
3.1.3.1 Cold roof

For this roof type, a protective geotextile layer is laid over the roof waterproofing layer and the build-up is then installed over this protective layer.



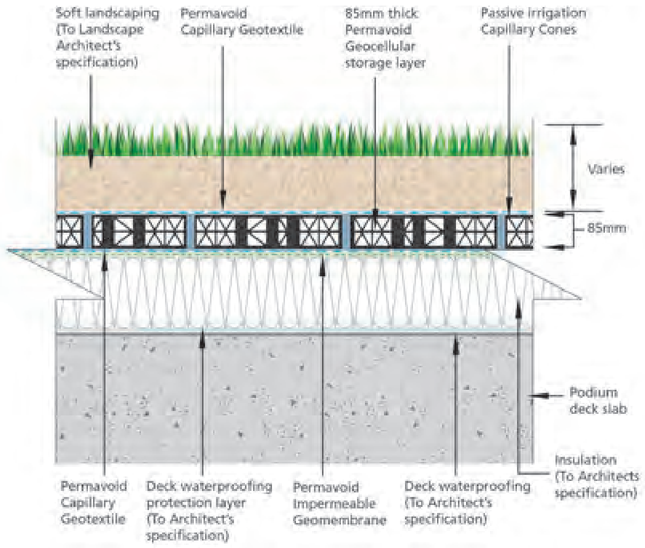
3.1.3.2 Warm roof

For this roof type, a protective geotextile layer is laid over the insulation and waterproof layer. The build-up is then installed over the protective layer.



3.1.3.3 Inverted roof

For this roof type, a supplementary waterproofing layer is installed over the roof insulation to provide further water tightness. The build-up is installed onto the waterproofing layer.



3.1.4 Amenity, biodiversity and resilience

By installing a Blue-Green roof system, biodiversity is assured – as a green space is created to mitigate loss of vegetation removed to construct the building, in addition to increasing the buildings resilience.

Furthermore, the system can be retro-fitted to existing roofs. By utilising the unique characteristics of the Blue-Green roof system a roof can be installed to provide amenity to the building users or for clients of a commercial operation. Different areas can be created through a mixture of hard and soft landscapes, recreational areas and sports and play areas.

3.1.5 Environment and sustainability

There are also potential benefits to the wider environment; for example improved air quality and a cooling effect as a result of the heat exchange process of evapotranspiration. But these outcomes require a large area of vegetation or a relatively dense grouping of smaller areas to provide a meaningful result.

Sustainable use of water is achieved as:

- Avoidance of wholesome (potable) water use for irrigation
- Ability to both retain water for irrigation and attenuate stormwater during peak rainfall events, controlling flows into the drainage system
- Efficient passive capillary irrigation – water used on demand from below. No inefficient loss due to evaporation (sprayed systems)

Covering roof membranes with Blue-Green geocellular solutions also protects the roof waterproofing system from UV radiation.

Conventional SuDS

To design the system, either stand-alone or linked, a detailed evaluation is required of the building's SuDS strategy.

Hydraulic calculations are needed to assess the critical rainfall events likely to be seen at roof level whilst structural calculations serve to confirm that the building can withstand the imposed loads from the roof build-up. Collaboration with the landscaping team would provide an understanding of the irrigation water volume required to be delivered to the vegetation.

Guidance for the specific design of a Green roof system is given in:

- SuDS Manual (C753) guidance – Chapter 12 Green roofs
- CIRIA C609 – Sustainable Drainage Systems: hydraulic, structural and water quality advice
- CIRIA C680 – Structural Design of Modular Geocellular Drainage Tanks
- CIRIA C644 - Building Greener. Guidance on the use of green roofs, green walls and complementary features on buildings
- The GRO Green Roof Code. Green roof code of best practice for the UK (2014)
- BS EN 12056-3:2000 Gravity drainage systems inside buildings. Roof drainage, layout and calculation
- DCLG (2013) Fire performance of Green roofs and walls
- BS 6229:2003 Flat roofs with continuously supported coverings. Code of practice
- BS EN 13252:2001 Geotextiles and geotextile related products. Characteristics required for use in drainage systems
- BS 8582:2013 Code of practice for surface water management for development sites

3.1.6 Design considerations

We have three stages of design for our Blue-Green roof system.

3.1.6.1 Hydraulic design

There is much to consider with Blue-Green roof design; interception characteristics, required peak flow control, the volume control of interception water and the exceedance flow design.

It's important to evaluate how the roof will behave in an extreme storm event and indeed at different times of year i.e. the interception characteristics are likely to be different during dry and warm periods compared to wet and cold periods.

The hydraulic design is based on guidance given in BS EN 12056 part 3 and CIRIA documents C680, C753, C723 and uses proprietary and, at times, bespoke software design packages to confirm the exact hydraulic characteristics and the type and number of rainwater outlets required, storage volume and the type, number and flow control characteristics of the rainwater outlets. If the Blue-Green roof is linked to other levels of the building or rainwater reuse systems, the design becomes more complex, as cascading attenuation levels will need to be considered. For design, the geocellular unit provides water storage (for use in capillary irrigation) and for attenuation of stormwater during critical rainfall events. The attenuation volume can be linked to reduced flow rainwater roof outlets to control the flow of water from roof level, taking it to downstream attenuation systems or direct to the outfall for the building. Exceedance flow design may incorporate systems, such as overflow pipes, to mitigate the effect of rainfall volumes greater than the peak design event.

3.1.6.2 Structural design

The project's structural engineer would ordinarily take the lead on the design of the roof area, ensuring the building design is able to accommodate the expected imposed loads.

These loadings may be those associated with the addition dead load from saturated substrate and vegetation, or, the live loads associated from additional wind loads on trees or large shrubs or human traffic within amenity areas.

3.1.6.3 Treatment design

The soil substrate, plant roots and capillary geotextile provide treatment for water as it infiltrates through the soil and into the geocellular unit. As this water is reused for capillary irrigation purposes, no further treatment would typically be required.

In the event that the system is linked to another reuse system, as a storage tank for pumped irrigation for example, then an appropriate risk assessment should be undertaken and the relevant treatment would be applied to that system. In the event of exceedance, treatment is applied by downstream drainage elements.

3.1.6.4 Other design considerations

Consideration is given to the wind effect at roof level and confirmation is required that the build-up of the roof provides adequate ballast to that build-up, to prevent up-lift.

Care should be taken for taller buildings where higher wind speeds might be experienced leading to greater up-lift forces and potential windburn to vegetation. Shielding should be considered to mitigate windburn.

Reference would be made to both the Approved Document Building Regulation Part B and the DCLG (2013) Fire Performance of Green roofs and Walls as to the fire performance of the Blue-Green roof and any requisite fire protection measures.

3.1.6.5 Landscape design and planting

The advice of a Landscape Architect or other such professional with experience of Blue-Green roofs should be sought to ensure the implementation of a sustainable planting scheme.

More extreme conditions, such as wind speeds, are seen at roof level and because of the low soil build-up there is less protection during cold periods as the ambient temperatures seen in soil at ground level are not present. Typical plant characteristics for an extensive roof should ideally be:

- Perennial or self-sowing
- Drought-tolerant
- Preference for well-draining soils
- Rapid establishment
- Self-sustaining
- Withstand extremes of temperature
- Withstand extremes of soil moisture content
- Low maintenance

For intensive roofs, these characteristics are less important as the roof would be accessible and typically require more maintenance. Plant types are selected for different reasons pertaining to Blue-Green roof performance and guidance is giving in CIRIA 753 - Chapter 12 - Table 12.4 (reproduced below). Further planting advice is given in The GRO Green Roof Code Best Practice for the UK (2014).

Planting for Green Roofs (from Dunnett, 2003)				
Depth of growing medium	Accessibility and visibility of roof			
	Inaccessible/not overlooked	Inaccessible/visible from a distance	Inaccessible/visible from a close distance	Accessible
0-50mm	Simple sedum/moss communities	Simple sedum/moss communities	Simple sedum/moss communities	Simple sedum/moss communities
50-100mm		Dry meadow communities/low growing drought-tolerant perennials, grasses and alpines, small bulbs	Dry meadow communities/low growing drought-tolerant perennials, grasses and alpines, small bulbs	Dry meadow communities/low growing drought-tolerant perennials, grasses and alpines, small bulbs
100-200mm			Semi-extensive mixtures of low medium dry habitat perennials, grasses and annuals, small shrubs, lawn/turf grass	Semi-extensive mixtures of low medium dry habitat perennials, grasses and annuals, hardy shrubs
200-500mm				Medium shrubs, edible plants, generalist perennials and grasses
>500mm				Small deciduous trees and conifers

3.1.7 Installation

Care must be taken to protect the roof's main waterproof membrane from puncture during installation and any subsequent damage to additional textiles and membranes.

It is possible for the hard engineering build-up – geotextiles, geomembrane, geocellular units, capillary geotextiles and associated control devices, to be laid some time before the growing medium and plants, therefore in this instance, ballast must be provided to prevent up lift by wind forces until such time as the growing medium is laid.

The growing medium should be laid directly over the capillary geotextiles that top the geocellular units. This is followed by applying the plants, which can be achieved in one of five ways – pre-grown mats, plugs or potted plants, cuttings and sprigs, seeding and self-seeding.

3.1.8 Operation and maintenance

It is likely that in the first 12 to 15 months, regular inspection and maintenance will be required to check that the Blue-Green roof has become established and is operating in the way intended.

Extensive roofs shall require little to no maintenance except for an annual or bi-annual inspection, whereas intensive roofs and areas with a high grass content would require regular maintenance; such as mowing, pruning and cutting back. This service is likely to be provided by the installer of the vegetation, unless the Building Owner or Facilities Manager have other options.

Inspections should also be carried out to fixings to the geocellular raft to ensure that they remain robust and connected to the hydraulic components, such as rainwater outlets and overflow devices, to ensure that they are operating correctly. It would also be necessary to remove any litter or silt build-ups at this time.

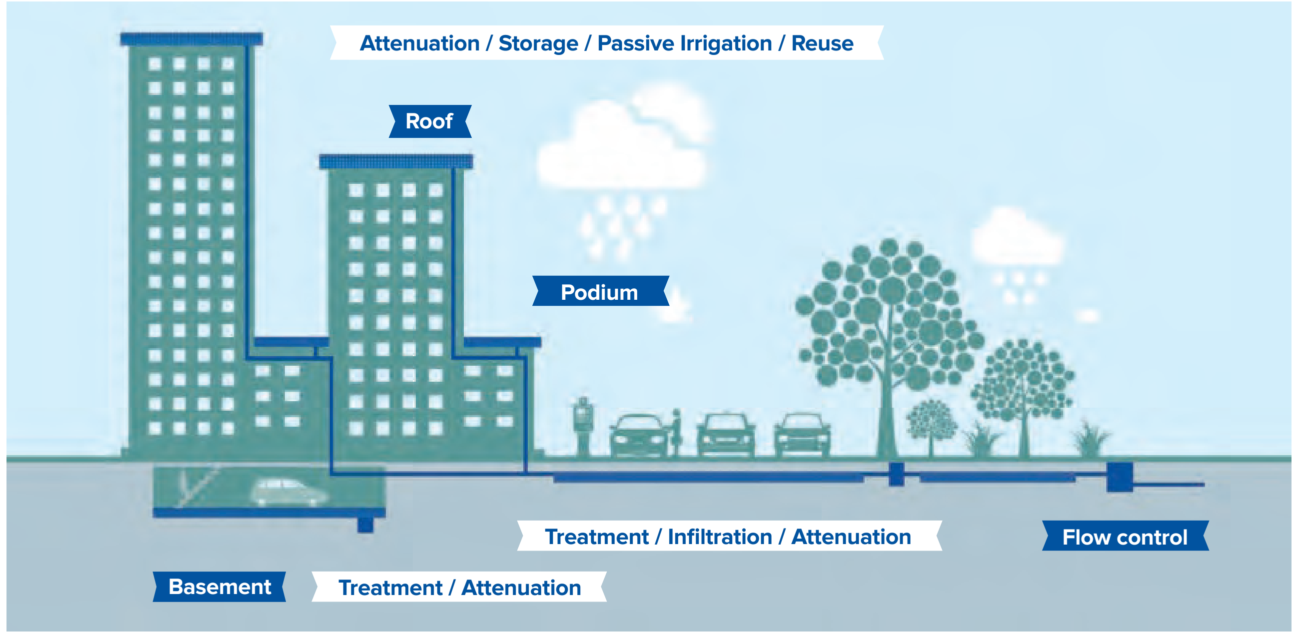
Inspection should also be increased after periods of high winds or excessive rainfall events to check that the Blue-Green roof area remains functional and that no health and safety matters have arisen. A typical operation and maintenance table is shown on page 252 (CIRIA 753 - Chapter 12 - Table 12.5)

Operation and Maintenance Requirements for Green Roofs		
Maintenance schedule	**Required action**	**Typical frequency**
Regular inspections	Inspect all components including soil substrate, vegetation, drains, irrigation systems (if applicable) membranes and roof structure for proper operation, integrity of waterproofing and structural stability.	Annually and after severe storms
	Inspect soil substrate for evidence of erosion channels and identify any sediment sources.	Annually and after severe storms
	Inspect drain inlets to ensure unrestricted run-off from the drainage layer to the conveyance or roof drain system.	Annually and after severe storms
	Inspect underside of roof for evidence of leakage.	Annually and after severe storms
Regular maintenance	Remove debris and litter to prevent clogging of inlet drains and interference with plant growth.	Six monthly and annually or as required
	During establishment (i.e. year one), replace dead plants as required.	Monthly (but usually responsibility of manufacturer)
	Post establishment, replace dead plants as required (where >5% of coverage).	Annually (in Autumn)
	Remove fallen leaves and debris from deciduous plant foliage.	Six monthly or as required
	Remove nuisance and invasive vegetation, including weeds.	Six monthly or as required
	Mow grasses, prune shrubs and manage other planting (if appropriate) as required – clippings should be removed and not allowed to accumulate.	Six monthly or as required
Remedial actions	If erosion channels are evident, these should be stabilised with extra soil substrate similar to the original material, and sources of erosion damage should be identified and controlled.	As required
	If drain inlet has settled, cracked or moved, investigate and repair as appropriate.	As required

3.2 Podium Decks

Polypipe surface water source control systems are designed to provide high volume shallow attenuation structures at both roof and podium levels of a building. The systems are designed to capture, treat, store and return surface water run-off to the underground drainage system in accordance with any prescribed site discharge rate.

These systems can provide a valuable contribution to a SuDS Management Train and include both the building and the wider environment. As they capture rainwater at source, the systems would take their position at the start of the SuDS Management Train.



Multifunctional benefits of podium decks

MAKING SPACE FOR WATER

Modular high void ratio geocellular units.

SURFACE WATER MANAGEMENT

Active and passive flow control at source (smart systems).

WATER QUALITY

Offers opportunities to treat water via Permeable Paving aggregate and proprietary components such as treatment geotextiles.

PLACEMAKING

Creating attractive green spaces in urban areas that wouldn't usually be available.

AMENITY

Creating functional green spaces that add amenity value in urban areas that wouldn't usually be available.

HEALTH & WELLBEING

Enabling the inclusion of spaces such as cycle paths, play areas, open spaces on podium areas that wouldn't otherwise exist.

BIODIVERSITY

Enables green spaces to be created, providing areas of high ecological value in urban environments with minimal maintenance.

EVAPORATIVE COOLING

Contributing to urban cooling via evapotranspiration from vegetation. Also reflects sunlight from the building fabric.

ASSET CREATION

Combination of green and retail spaces offers possible further revenue streams.

3.2.1 Increased attenuation capacity in podiums

Additional attenuation storage capacity may be provided within the pavement construction by substitution of the sub-base material with Permavoid units, offering additional attenuation storage benefits, due to the unit's significantly higher porosity. The Permavoid unit having a nominal porosity of 95%, compared with a typically assumed granular sub-base material porosity of 30%.

The Permavoid system forms a unique high strength structural raft, complying with the British Standard (BS 7533-13:2009) design guidance for permeable pavements constructed from engineered and natural pavers. Permavoid units can also behave as a conduit, provided a continuous installation is maintained across the pavement cross section, with flows typically driven by hydraulic head. This form of construction may also be used with pavement gradients steeper than 3%, provided appropriate check dams are created within the structure. These check dams may be formed through the creation of geomembrane barriers, in additional to the optional use of geofoam units as an effective flow control. Permavoid units having a uniform shape and high porosity, in addition to offering a higher flow resistance than conventional pipe systems, which would further slow the flow of water through the system.

Permeable surface

To be installed directly onto the capillary geotextile or via an intermediary bedding layer. This is the main mechanism via which surface water enters the Permavoid attenuation raft.

Permavoid 85mm cell

Permavoid 150mm cell

Non-permeable surface

Can also be laid provided methods of treatment are installed alongside the Permavoid raft. Permachannel and Permaceptor are examples of linear and point treatment devices. The Permachannel and Permaceptor treat hydrocarbons to 12ppm.

Oil retention and water quality

Available in two grating options, Permatreat is a versatile, linear treatment system that can provide source control and pollution treatment in a wide variety of locations and applications. The Permatreat channel functions as a combined run-off collection system, whilst intercepting silt and oil from surface water run-off.

Permachannel
(Image for illustration purposes only)

Permatreat
(Image for illustration purposes only)

Structural raft

The Permavoid 85mm and 150mm cells are connected with Permaties creating a structural raft and considered as a cold roof build up unless otherwise specified.

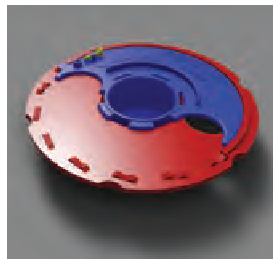
Permaceptor

3.2.2 Controls

The Polypipe Source Control system can be linked to control and monitoring systems as a stand-alone unit but also linked to other downstream water management systems.

As an example, we can link the outlets from the roof or podium to downstream capture and reuse systems where non-potable water can be used for applications such as WC flushing and plant irrigation.

Adjustable reduced flow rainwater outlet



A cartridge that fits into standard Terrain PVCu roof outlets that allows the aperture to be adjusted to regulate the flow rate into the rainwater pipes. This is instrumental in meeting any prescribed rate of surface water outfall from a site.

INTRODUCTION
3.1 BLUE-GREEN ROOFS
3.2 PODIUM DECKS
3.3 TREES
3.4 SPORTS PITCHES
3.5 CYCLE PATHS
3.6 PERMEABLE PAVEMENTS
3.7 BIORETENTION SYSTEMS
3.8 ATTENUATION STORAGE TANKS
3.9 INFILTRATION SYSTEMS
3.10 SWALES
3.11 FILTER DRAINS
3.12 DETENTION BASINS
3.13 PONDS AND WETLANDS
3.14 FILTER STRIPS

3.2.3 Conventional SuDS

The benefits of capturing water at source are:

- Reduction in volume of downstream deep dig attenuation systems
- Removal of water capture tanks from areas such as the basement – freeing up saleable space such as car parking
- Areas can be integrated at all levels to provide multi-use amenity and replacement of bio-diversity with our Blue-Green roof system
- Reduction in rainwater/surface water pipe diameters, particularly at collector pipe level

Water is captured through different methods dependent on area application. At roof level permeable surfaces allow infiltration into the attenuation system whereas at podium level, permeable surfaces are used in non-trafficked areas. In trafficked areas, non-permeable surfaces might be required in order that further treatment can be provided via treatment drainage channels prior to the water entering the attenuation system. If a roof is cascading onto a podium surface, discharge chambers incorporating basic treatment can be installed to provide controlled transition into the podium attenuation system.

By utilising the Permavoid geocellular unit or sub-base high strength characteristics, podium areas can be trafficked allowing multi-use areas to be designed.

Source control systems are designed so that there is a level of water held at roof and/or podium during a rainfall event and allowed to discharge from these areas at a known controlled flow rate. Geocellular units or sub-base can provide attenuation. It should be noted that although water is held at roof level, the design limit is always below the maximum geocellular height for the critical storm event and, through hydraulic design, there is a maximum time of 24hrs for the system to be fully empty. In practice the time to empty is always significantly below this time limit and the time to half empty is typically 1-5hrs. Therefore, source control systems are designed to remove water from a roof or podium effectively, but over a longer time period than a traditional gravity or siphonic rainwater system.

Source control systems can be designed as a stand-alone system, however there is now more demand to link systems at various roof and podium levels. This would enable a building to further link to a rainwater capture and reuse system in order that the surface water run-off discharged is directed to storage for reuse for non-potable applications – such as WC flushing or plant irrigation. Control systems that link different areas of attenuation and different applications to ensure the building water management strategy is fully integrated. It should be noted that by utilising the high strength characteristics of Permavoid, podium areas can be trafficked allowing further multi-use areas to be designed.

To design the source control system, either stand-alone or linked, a detailed evaluation is required of the building's SuDS strategy. Hydraulic calculations are needed to assess the critical rainfall events likely to be seen at roof and/or podium level and potential downstream implications. Structural calculations serve to determine whether the areas can support the imposed loading of run-off water as it drains away as well as any build-up required above the attenuation system.

Guidance for the specific design of Source Control attenuation can be found in (but not exclusive to) :

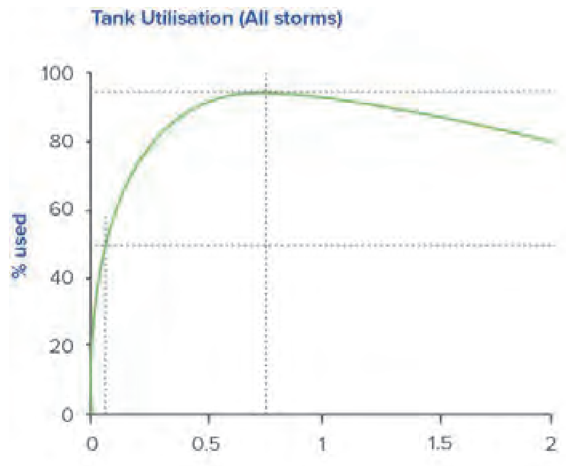
- SuDS manual (C753) guidance – Chapter 10
- CIRIA C609 – Sustainable Drainage Systems: Hydraulic, Structural and Water Quality Advice
- CIRIA C680 – Structural Design of Modular Geocellular Drainage Tanks
- CIRIA C156 - Infiltration Drainage – Manual of Good Practice
- BS EN 12056-3:2000 Gravity drainage systems inside buildings. Roof drainage, layout and calculation
- BS EN 13252:2001 Geotextiles and geotextile related products. Characteristics required for use in drainage systems
- BS 8582:2013 Code of practice for surface water management for development sites

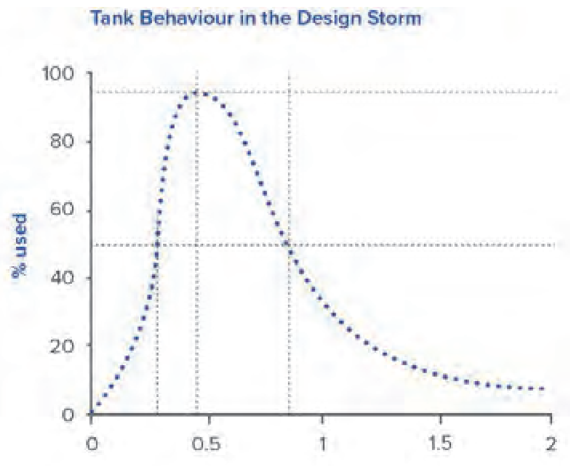
3.2.4 Hydraulic design

Hydraulic design should consider the interception characteristics of the proposed surface, the peak flow control required, the volume control of interception water and the exceedance flow design.

It is important to understand how the surface behaves in an extreme storm event in order to react appropriately to successfully mitigate exceedance events.

This example of hydraulic design is based on guidance given in BS EN 12056 part 3, BS 8582 and CIRIA documents C680, C753, C723 and uses proprietary and, at times, bespoke software design packages to determine the exact hydraulic characteristics, storage volume and the type, number and flow control characteristics of the rainwater outlets. The times for half empty and fully empty are also provided for the critical storm event so the designer can understand ***a***. the maximum fill level of the Permavoid attenuation raft and ***b***. how quickly this event shall be dissipated by the attenuation system.





If the source control area is linked to other levels of the building or rainwater reuse systems, the design becomes more complex as cascading attenuation levels will need to be considered. Polypipe's design service is able to accommodate this across a range of levels and applications.

Exceedance flow design incorporates systems, such as overflow pipes, to mitigate the effect of rainfall volumes greater than the critical storm event.

3.2.5 Structural design

A structural engineer would ordinarily take the lead on the design of the podium or roof area with the space considered and designed to accommodate the imposed loads.

For more information regarding designs at Podium level please refer to Permeable pavements section page 163.

3.3 Trees

Within the UK, trees have been used to enhance the urban environment for a significant period of time, with urban forestry pioneered in the 19th century.

It has been widely recognised that trees are able to improve the quality of an urban environment and contribute a wide range of additional socio-economic and health benefits. This includes improving air quality and the micro climate around them, to reducing wind speeds, absorbing sunlight, cooling the air and shading adjacent buildings and surrounding ground areas. The magnitude of these beneficial effects is generally dictated by the tree canopy size, which is influenced by the tree species, general health and maturity. Urban trees have also been shown to offer numerous additional economic and social benefits, through the generation of higher local property values and rental income, along with contributing to an increase in local residents' health and wellbeing.

Both retention of existing trees and new tree planting within a development should be considered at the earliest possible planning stage, to ensure space is made which allows the inclusion of mature trees, that meet the local development needs while maximising the adjacent benefits.

This includes an appreciation of the overall landscape design objective, in addition to practical consideration such as:

- **above ground street furniture (e.g. street lighting)**
- **below ground infrastructure (e.g. utilities)**
- **required sight lines (i.e. CCTV)**

for the full design life of the tree; 60 years being a typical target.

Within a SuDS context, tree systems are effective in offering the following water management benefits:

- **interception**
- **total discharged volume reduction**

Multifunctional benefits of trees

MAKING SPACE FOR WATER
Modular high void ratio geocellular units, enables the sustainable management of tree installation. Creates a void for tree growth combined with attenuation capacity.

SURFACE WATER MANAGEMENT
Interception of rainfall by tree canopies reduces total volume of water discharged into the drainage system.

WATER QUALITY
Offers source control treatment of silt via soil matrix and inclusion of treatment geotextiles.

PLACEMAKING
Tree systems can be designed to easily fit within a development, providing aesthetically appealing green features within an urban environment.

AMENITY
Creating functional green spaces which include trees adds further amenity benefits.

HEALTH & WELLBEING
Inclusion of trees in developments that are accessible or overlooked can increase mental wellbeing.

BIODIVERSITY
Enhancing urban wildlife, provides habitat for lots of species, increases/aids landscape connectivity between green areas.

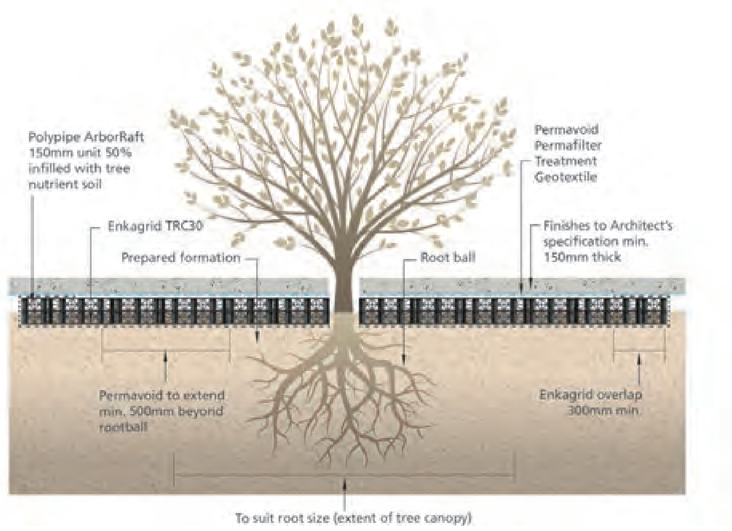
EVAPORATIVE COOLING
Tree canopies can provide shade for cooling, and evaporate intercepted stormwater from the leaves (evapotranspiration). Can also reflect sunlight.

ASSET CREATION
Research has proven that trees provide significant benefits for developers and property owners by increasing property values and selling prices. Studies determine that large street trees were the single most important indicator of attractiveness in a community.

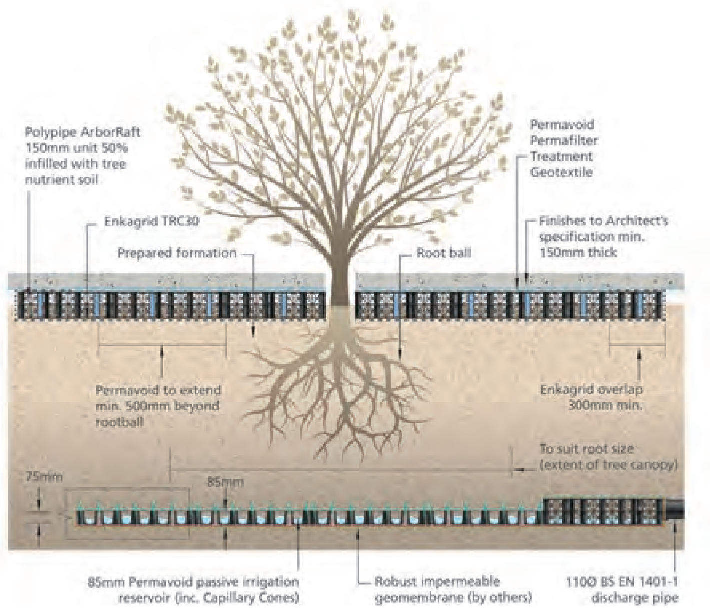
3.3.1 Raft systems

Raft systems are used to create a protective structural layer above tree root systems.

Typically installed to effectively create a load transfer platform that distributes concentrated loads (i.e. wheel loads) over a greater area, to protect the underlying soil structure. They may be infilled with granular material to provide additional structural raft rigidity, or when used beneath impermeable surfaces, they may be left open to provide an effective means of allowing the free movement of gases and water to the tree root system. During tree establishment nutrient rich soil can be brushed into the Permavoid units to allow the nutrients to leach down into the root ball for use by the tree.



Typical Permavoid protective raft detail; used to protect existing tree root systems beneath paved or trafficked areas.



Typical Permavoid protective raft and underlying passive irrigation system; used to protect new tree pit rooting zone and create additional water storage and sustainable irrigation.

3.3.1.1 Polypipe ArborRaft for NEW trees

The unique ArborRaft system spreads the load ensuring there is no compaction of the soils around the tree roots, maintaining the perfect environment for the trees to establish and mature providing the benefits that healthy trees bring to our towns and cities.

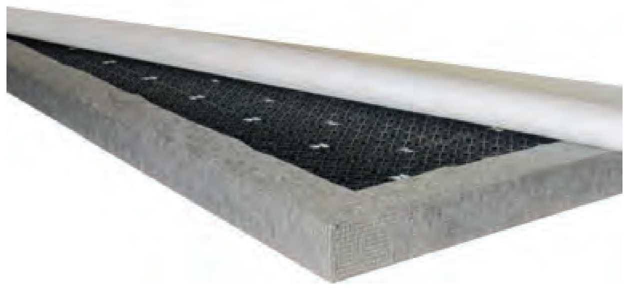
Oxygen and water levels can be managed and improved within the ArborRaft system. All types of vehicle loadings can be accommodated, from cars through to Heavy Goods Vehicles.

The ArborRaft system can be incorporated into a development's sustainable drainage design. The system has a 90% void ratio which may be used to store surface water run-off to assist with flood prevention.

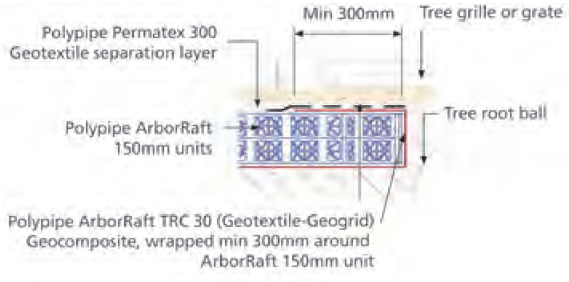
This water may be reused if required as grey water or attenuated to restrict flow rates from site to meet local environmental standards.

The ArborRaft system can also be used in basement construction for insulation and structure protection against the ingress of deep tree and plant rooting systems. The ArborRaft creates a high strength structural air void that acts as the perfect barrier against the ingress of deep rooted tree and plant roots into below ground structures, thus reducing the damaging effects this can have.

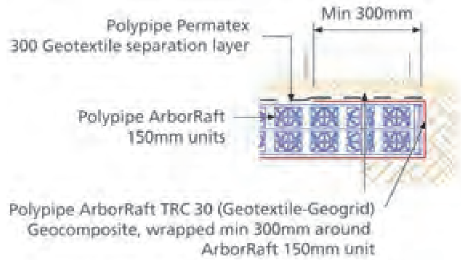
By making use of the ArborRaft units, walls can be ventilated and underground hollow spaces are created. These also serve as a growth barrier for tree roots. As a result, cables, pipes and other underground structures are protected.



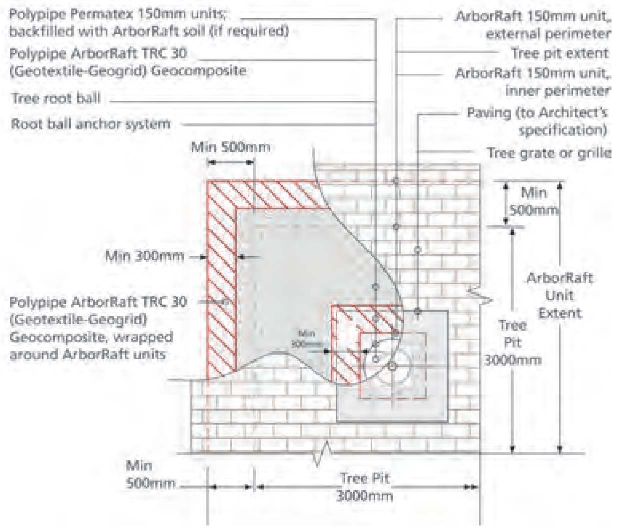
Parking spaces around trees.



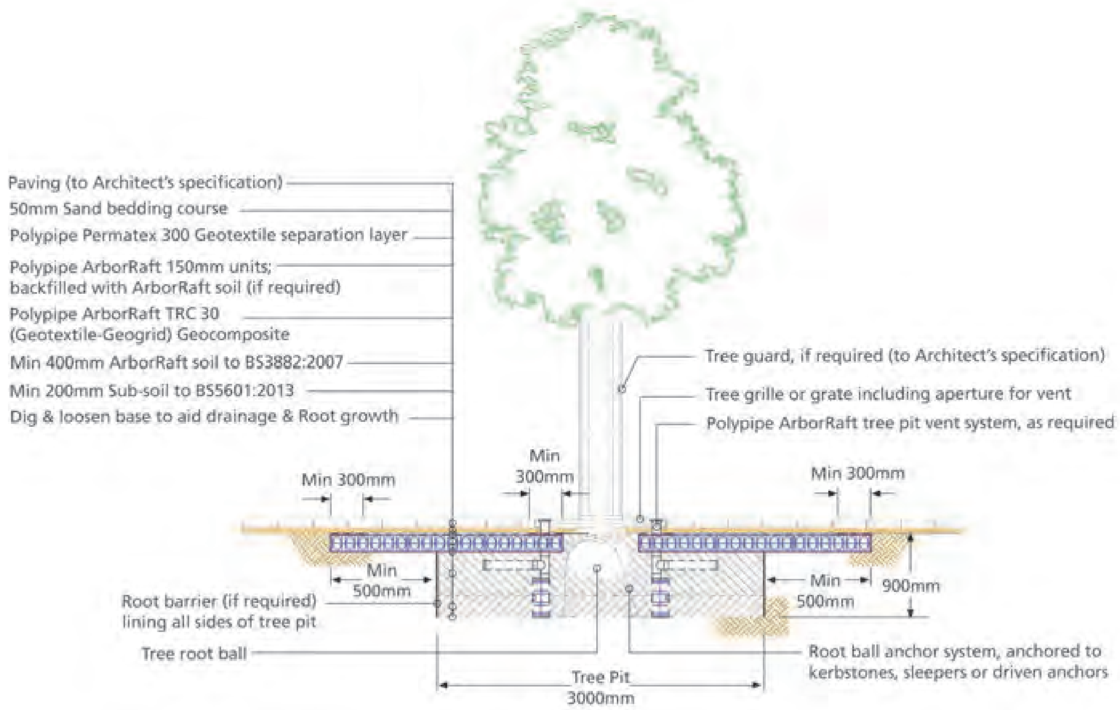
Critical Raft Edge Detail Inner Perimeter



Critical Raft Edge Detail Outer Perimeter

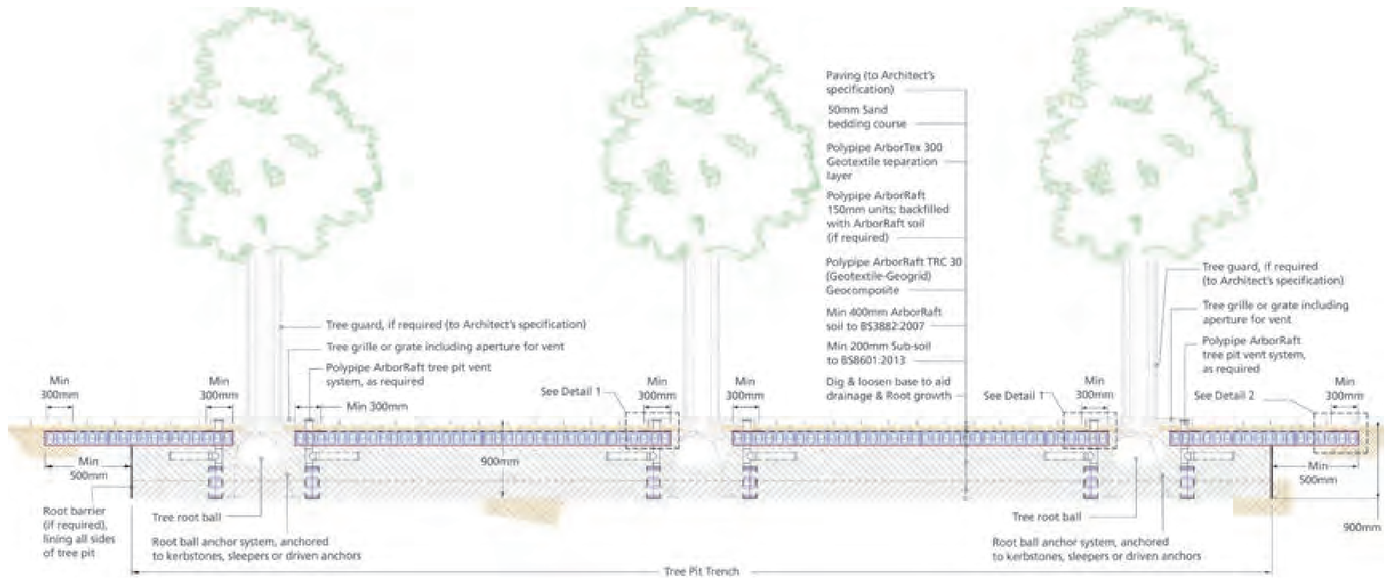


Plan view

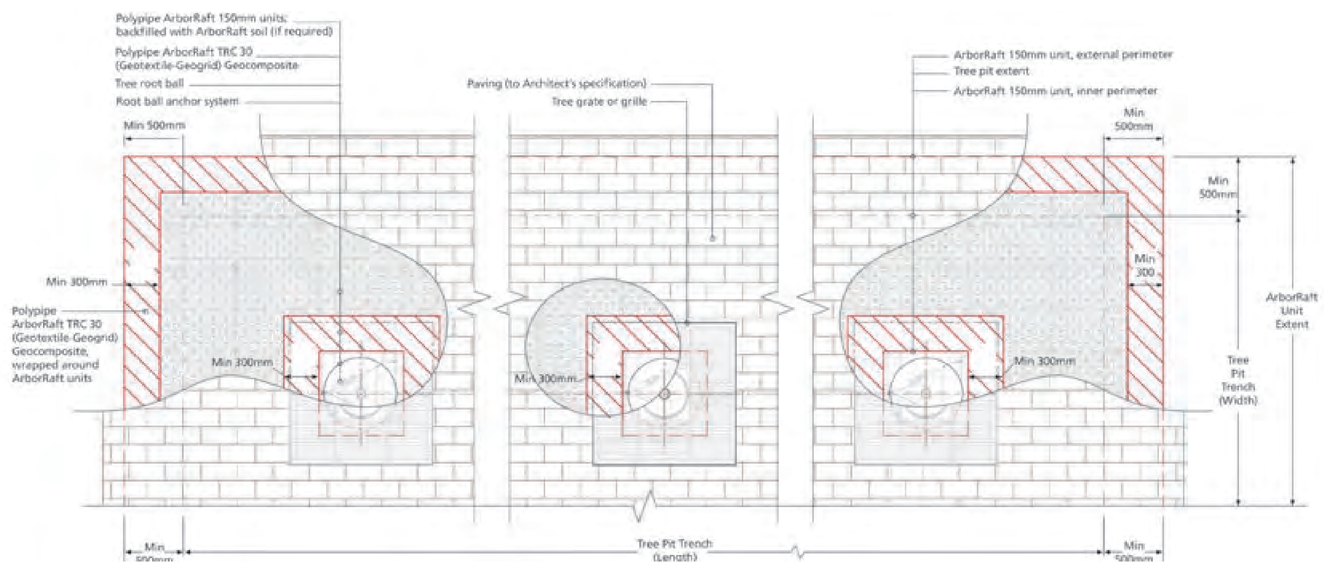


Front view cutaway

INTRODUCTION
3.1 BLUE-GREEN ROOFS
3.2 PODIUM DECKS
3.3 TREES
3.4 SPORTS PITCHES
3.5 CYCLE PATHS
3.6 PERMEABLE PAVEMENTS
3.7 BIORETENTION SYSTEMS
3.8 ATTENUATION STORAGE TANKS
3.9 INFILTRATION SYSTEMS
3.10 SWALES
3.11 FILTER DRAINS
3.12 DETENTION BASINS
3.13 PONDS AND WETLANDS
3.14 FILTER STRIPS



Typical Section

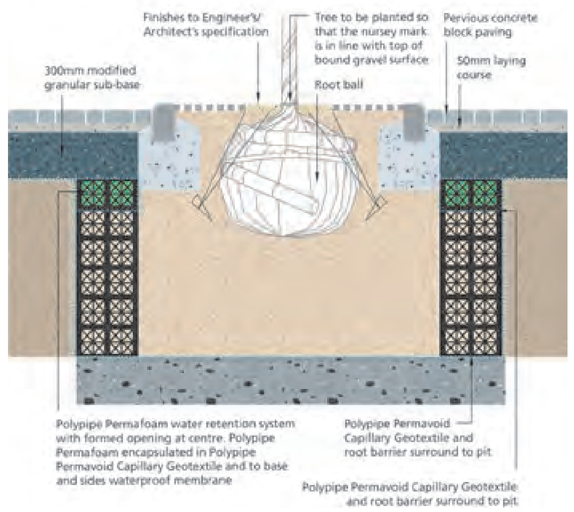


Plan view

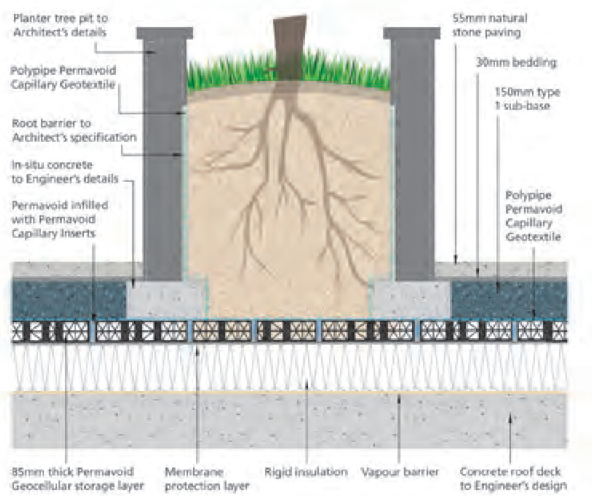
3.3.1.2 Modular structures

Geocellular structures that have a high porosity and load bearing capacity, which are typically used to partially or completely replace aggregate and stone substrate.

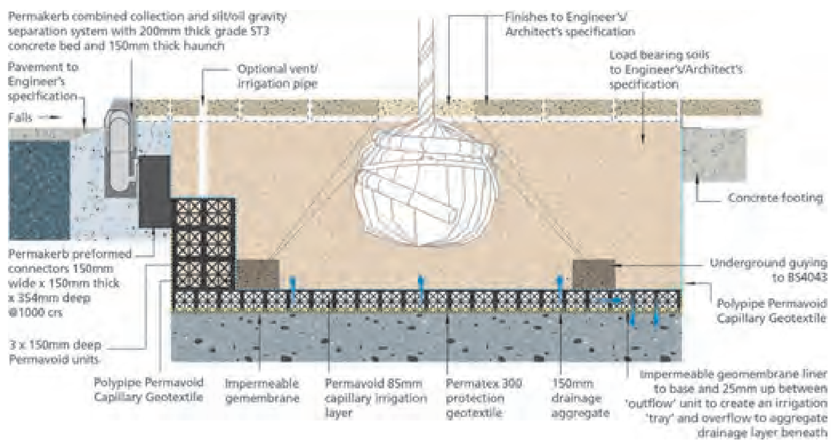
The Permavoid units support the imposed vehicle loading, while providing protection to a non-compactable zone that may be infilled with growing media. They may also be used to provide additional surface water attenuation storage, or through careful design, water retention that may be utilised for irrigation purposes. Refer to diagrams below for typical examples of Polypipe Permavoid units being used to create tree pits and water retention systems respectively.



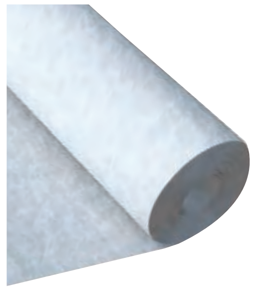
Tree pit with Permavoid perimeter; offering lateral protection to growth medium from over compaction.



Raised planter example; utilising underlying Permavoid water retention and passive irrigation system



The individual key components are as follows:



Permafilter geotextile

Permavoid 85 geocellular unit

Permavoid 150 geocellular unit

Permatie

Shear Connector

Permafilter geotextile (Section 2.4)

Use Permafilter geotextile in an addition to, or replacement of, the transition layer.

Permavoid 85 & 150 geocellular units (Section 2.4)

High load bearing and porosity modular units, providing significantly greater storage capacity compared with soil and aggregate media.

Permavoid Capillary Cones

Highly absorbent cones which use capillary action to transport stored stormwater upwards which may then be used for irrigation of the surface above.

Permavoid capillary geotextile (Section 2.4)

Used in conjunction with Permavoid Capillary Cones units, allows soil moisture content to be maintained.

Permavoid^2 85 (Section 2.4)

Six pre-connected units designed to provide attenuation for shallow non-loaded applications ideal for roof and podium deck applications.

Permaties and Shear Connector (Section 2.4)

A patented tapered tie that interlocks the Permavoid cells into a secure and consistent raft. When two or more layers of Permavoid are used to form a structure, Shear Connectors are inserted between the layers to create a stability and shear resistance to prevent lateral movement.

ArborRaft Aeration unit

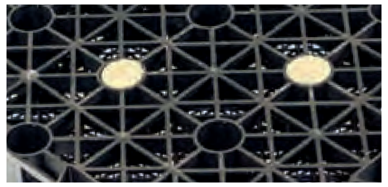
Product code: AS150AU

Multi Tree Cap 80mm

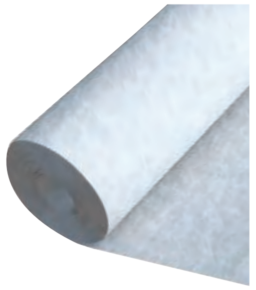
Product Code: ASMTC80

Multi Tree Cap Tile 300 x 300 x 80mm

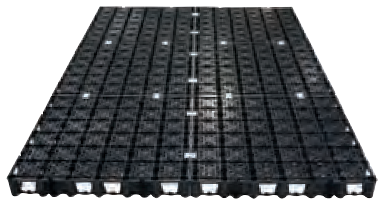
Product Code: ASMTCT300



Permavoid Capillary Cones



Permavoid capillary geotextile



Permavoid^2 85

3.3.1.3 Polypipe ArborRaft for EXISTING trees

The damage caused by tree roots lifting pavements and disturbing services is now eradicated by using the ArborRaft system.

The root structure is provided with a healthy growing area which is left uncompacted and with access to water and constant nutrient feeding if required. Tree roots do not tend to break through pavement surfaces when their rooting environment is so similar to that of a natural forest floor and the ArborRaft system helps create a natural air barrier preventing roots from penetrating the surfaces.

3.3.1.4 Damage to existing trees on development sites

There are a number of ways trees are damaged during construction:

- Unspecified or poorly implemented treeworks
- Poorly installed tree protection fencing/ground protection
- Unauthorised or poorly undertaken excavations for service trenches in close proximity to retained trees
- Storage of materials within retained tree Root Protection Area
- Contamination of tree rooting zones directly or indirectly by; concrete run-off/washings, mortar silos, diesel, tarmacadam, chemicals etc
- Compaction of tree rooting zones by temporary construction site access for delivery vehicles, materials storage etc
- Compaction damage by waterlogging of tree rooting zones
- Damage by burning fires on-site too close to retained trees

Soil compaction causes the reduction in available air spaces within the structure of the soil, a vital component tree roots require to respire, grow and regenerate. By compacting the soil around tree roots the tree's ability to absorb available ground water is reduced as associated symbiotically growing fungal Mycorrhiza attached to and around those roots decline. This in turn affects the tree's ability to absorb not only water, but also nutrients which detrimentally affects the vigour and growth of the tree, causing 'stress'. This manifests itself in smaller, yellowing leaves, a reduction in crown vigour and shoot/twig extension, higher crown deadwood – in particular of the upper crown – which can lead to branch failure or even tree decline if not alleviated.

3.3.1.5 BS5837 (2012) trees on construction sites

This document provides guidance for the management of existing trees on construction sites identified for retention as part of the survey and reporting process by a qualified Arboricultural consultant.

Where tree retention or planting is proposed in conjunction with nearby construction, the objective should be to achieve a harmonious relationship between trees and structures that can be sustained in the long term. The good practice recommended in the British Standard is intended to assist in achieving this objective.

BS 5837:2012 is applicable whether or not planning permission is required. BS 5837:2012 follows a logical sequence of events that has tree care at the heart of the process. The full sequence of events might not be applicable in all instances; for example, a planning application for a conservatory might not require the level of detail that needs to accompany a planning application for the development of a site with one or more dwellings.

The 2012 revision of the standard introduces the following principal changes:

- Takes account of current practice regarding planning for the management, protection and planting of trees in the vicinity of structures, and for the protection of structures near trees
- Updates the guidance in relation to building regulations
- Recognises the contribution that trees make to climate change adaptation

3.3.1.6 InfraWeb TRP

Polypipe is focused on maintaining and improving green urbanisation in the built environment. We have a number of tree root protection systems for the protection of both existing and newly planted trees.

InfraWeb TRP has been developed to provide a cost-effective solution to the problems associated with providing load support for new hard surfacings above existing tree roots on development sites.

InfraWeb TRP is a 3-dimensional cellular confinement system used to construct vehicular access roads, parking areas etc around the RPA of existing trees. The system is manufactured in accordance with the original U.S. Army Engineers Corps specification and conforms to the requirements of BS5837 and APN12. The system is available in five depths: 50mm, 75mm, 100mm, 150mm and 200mm.

InfraWeb TRP Product Specification

Property	Test Method	Unit	Value				
Wall Thickness (Textured)	ASTM D5199	mm	min 1.25 ± 0.15/min 1.25 ± 0.15				
Unit Height		mm	50	75	100	150	200
Cell Walls			Textured and Perforated (11% ± 2%)				
Distance Between Welds		mm	292				
Expanded Unit Width		m	2.42				
Expanded Unit Length*		m	8.0				
Coverage*		m²	19.3				

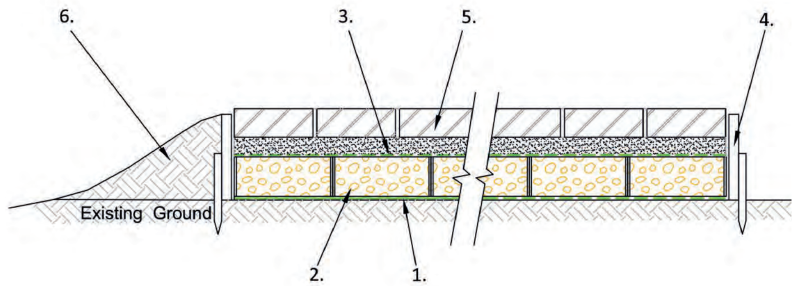
*Other length and coverage available upon request. (Length, width and coverage dimensions are for square cells)

Key

1. ArborTex Geotextile
2. InfraWeb Tree Root Protection System infilled with 4/20 or 20/40 clean angular stone to BS EN 13242/EN 12620*
3. ArborTex separation geotextile
4. Treated timber edging (or other edging detail acceptable)
5. Block paving with sand bed to engineer's specification
6. Soil graded to edging (if required)

Benefits

1. No dig solution
2. Reduces compaction of subsoil around tree roots
3. Reduces sub-base thickness
4. Allows clean angular stone to be used within the cells
5. Dissipates vertical loads
6. Allows air and moisture transfer



InfraWeb TRP

Typical Section Detail

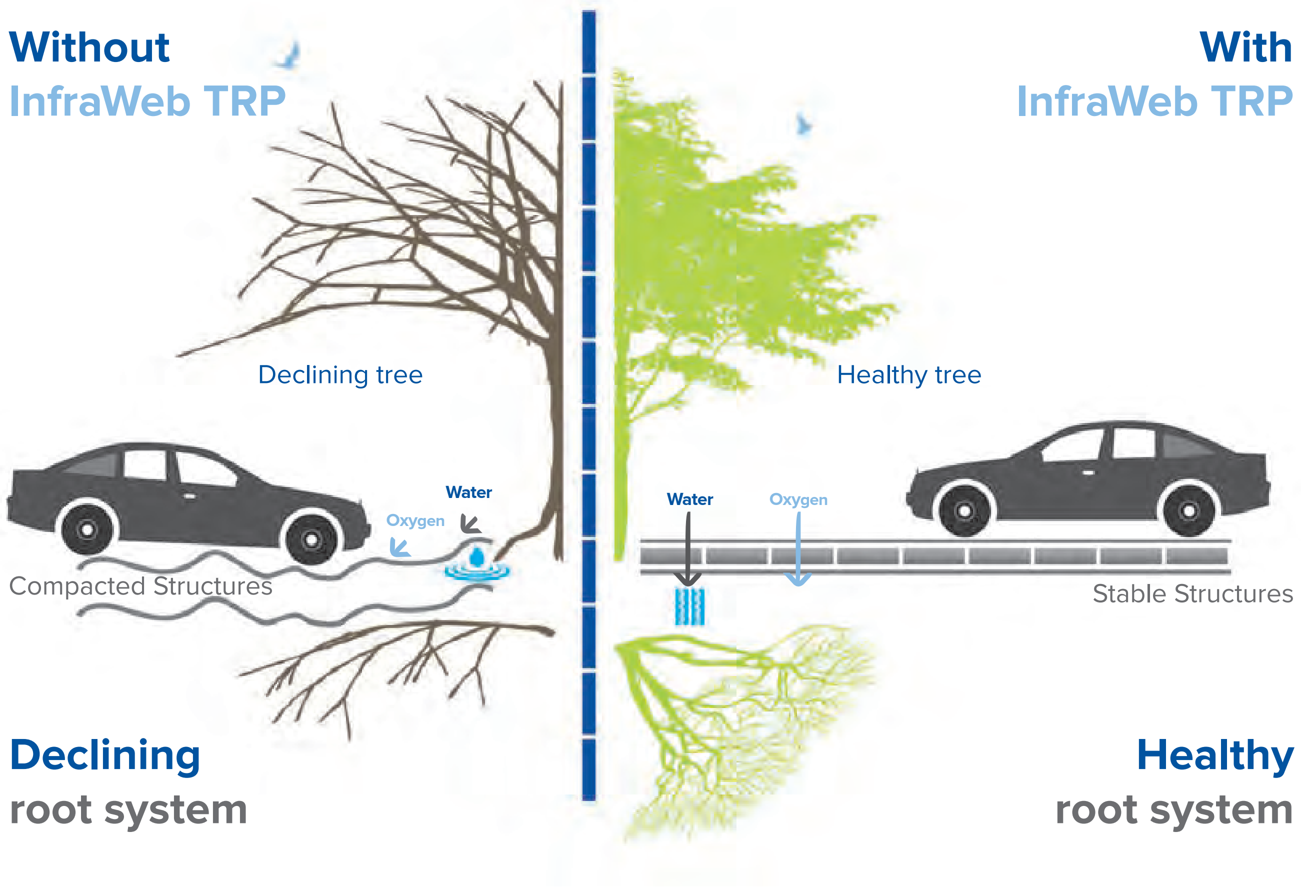
InfraWeb is guaranteed to be durable for a minimum of 50 years in natural soils with 4<pH<9 and soil temperatures of up to 25 deg C.

*InfraWeb height dependent on site specific design requirements

3.3.1.7 System benefits

Vehicular traffic over unprotected areas within the tree root protection zones of existing trees, causes compaction of sub soils, leading to reduced voids within the soil structure.

This causes major problems with aeration and water transfer to the roots themselves which, ultimately, can lead to the root structure declining and eventual tree loss.



Water and Oxygen transfer through the InfraWeb TRP System

BS5837 (2012) recommends the use of a 3-dimensional cellular confinement system for use as appropriate sub-bases for new hard surfacing over the RPA of existing trees.

The hard wearing, stable and free-draining structure created using the InfraWeb TRP system prevents soil compaction, whilst maintaining water and air flow to the roots by using 4/20 or 20/40 clean, angular stone for infill. This material will always be more permeable than existing soils, ensuring free flow of air and water to the trees is achieved.

3.3.2 Hydraulic benefits

Trees are effective in offering the following water management benefits:

- interception, both above and below ground;
- **Above ground**
  The tree canopy and trunk intercept rainfall, before it reaches the ground, both absorbing and storing rainwater prior to it evaporating.
- **Below ground**
  Retention of surface water within the system soil matrix.
- Transpiration of water drawn from the tree root zone, via the tree foliage
- Increased water infiltration, through the maintenance of soil infiltration rates through tree root growth and decomposition
- Pollution treatment, via phytoremediation of polluted water taken up by a tree, in addition to biodegradation within the soil matrix

In addition, volume and flow rate control can be provided within the system, following the introduction of an appropriate flow control device at the system discharge point and provision of attenuation storage beneath the level of the tree root system. It should be noted that the majority of tree root growth typically occurs within the upper 1.0m of soil and significant growth does not occur at depths circa 2.0m. This is assuming that boundary conditions are not created when the system is installed, which limits root growth; although it should be noted that this would also impact tree development and growth once the root zone has reached the extents of the system installation.

Where significant infiltration of surface water is not viable, tree systems are still able to offer a number of hydraulic benefits. Surface water entering the drainage system is slowed, due to it having to percolate through the soil matrix. They are also able to contribute to interception, as trees require significant volumes of water to maintain healthy growth, in addition to the soils offering a significant storage capacity within its matrix.

The engineered soils within a tree system can also be expected to have a minimum porosity, offering a degree of attenuation storage within the drainage system. The engineered soil porosity may be maintained through the growth and decomposition of the tree root system.

(SuDS Manual (C753) guidance – Chapter 19.9; typical structural soil specification)

The drainage of the system can be facilitated with the creation of an underdrain system at the base of the installation, with the inclusion of a perforated pipe or adjacent collection chamber, to increase the water management options. The underdrain system below the root zone can be used to provide specific attenuation storage prior to its discharge from the system.

Where the system discharges to a downstream drainage system, a flow control may be introduced at the system outlet, with the drainage layer then used to provide attenuation storage. Attenuation storage capacity can be increased within the system by providing a thicker drainage layer, or by introducing proprietary surface water storage systems within the layer (i.e. geocellular units), as a replacement to the granular material.

3.3.3 Polypipe enhancement

Formation of a drainage layer (underdrain) beneath the engineered soil of a tree system, including the installation of a perforated pipe to assist in the draining of the system.

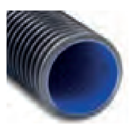
Polypipe is able to offer a number of product ranges that can be used for this application:

Landcoil

PVCu single-walled flexible pipe system manufactured to BS 4962. Available in diameters from 60-200mm.

Linflex Fin and Narrow Filter Drains

For applications where sub-surface only drainage is required, e.g. low capacity drainage for keeping water out of road structures, Fin and Narrow Filter drains may be used as an alternative. These products are for use in edge-of-pavement drains for the collection and/or disposal of sub-surface water in accordance with the requirements of Highways England.



Ridgidrain

Thermoplastic structured walled surface water pipe system. Available as carrier, half perforated and fully perforated in diameters 100-900mm.

In instances where infiltration from the tree system is not viable, provision of an appropriate flow control(s) downstream of the system within the drainage system should be made. Consideration may also be given to increase the potential attenuation storage provided by the tree system. This increase in attenuation storage can be achieved through substituting an underdrain pipe or drainage layer for a geocellular unit from our Polystorm or Permavoid product ranges.

3.3.4 Water treatment

Polypipe geocellular systems offer additional attenuation benefits, due to the unit's uniform shape and high porosity.

These units may also be used to link multiple tree system installations (i.e. tree pits), where a continuous installation is maintained, with the units behaving as a conduit, with flows typically driven by hydraulic head.

Where Polypipe geocellular systems are used in conjunction with our passive irrigation system components, significant reductions in the total surface water discharge from the site can be achieved (30 – 175 m^3/tree/year, depending on maturity) by meeting the water demand of a thriving tree.

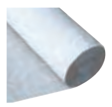
Polypipe is able to offer a range of pre-fabricated chambers, designed to facilitate the simple inclusion of a range of flow controls in the drainage system.

A tree installation designed to maximise potential growth and offer soil conditions suitable for the whole range of commercially available tree species, would offer minimal direct surface water treatment benefits compared to a 'bioretention' system, due to the need for maintenance of optimal soil moisture levels (i.e. unsaturated).

Significant reductions in the potential pollution impact of surface water run-off can be obtained through the attenuation of run-off generated by high frequency rainfall events, typically approximated by a 5mm rainfall depth. Tree systems can offer opportunities to provide interception through:

- tree canopy interception of rainfall, before it reaches the underlying impermeable surface
- attenuation within the soil matrix that supports the tree; in addition to within the underlying engineered soil and drainage media
- evapotranspiration

Where a water retention and passive irrigation system is considered, this arrangement would retain a high proportion of initial run-off, especially when directly connected to a roof or impermeable surface collector discharge pipe. In this instance, careful consideration should be given to the design of the system overflow or exceedance flow routes, in order to minimise the risk of damage to the tree(s).



Permafilter geotextile

Use Permafilter geotextile as the filter between the engineered soils and drainage layer; offering additional hydrocarbon treatment benefits.

3.3.5 Treatment benefits

Polypipe surface water conduit and storage products can be used to manage the maximum water flows through other SuDS elements.

This enables the treatment efficiency of the other SuDS elements within the treatment train to be maximised. They can also enable the choice of SuDS options available to a Designer to be maintained, even on constrained sites where space availability may otherwise be used to excuse their exclusion. Installation of Polypipe's range of associated fabrication chambers can be used to facilitate the inspection and maintenance of infiltration systems, particularly where they extend over a significant distance or interface with other drainage systems.

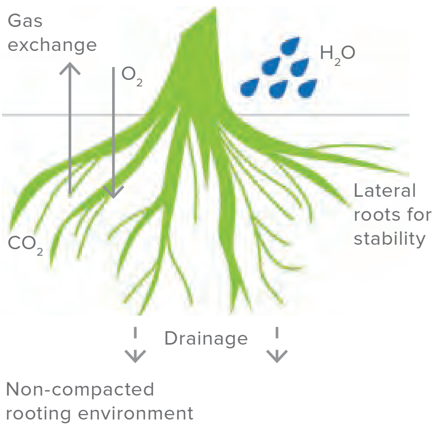
3.3.6 Conventional SuDS

Trees may essentially be planted as a standalone installation (i.e. tree pit), with linear installations created through connecting multiple tree pits, either via surface (i.e. swale) or below ground (e.g. continuous geocellular installation) drainage elements.

Trees may be included within a range of SuDS systems to create a distinctive feature, or integrated within a bioretention system, typically in combination with other bioretention vegetation. Where it is proposed to incorporate trees within a bioretention system, careful design, selection of tree species tolerant to the prevailing ground conditions and specification of the system is required. To ensure the risk of significant detrimental effect to tree growth is minimised, an appropriately qualified and experienced tree expert should be consulted, or as a minimum reference made to BS 8545:2014. Please refer to Section 3.7 for further information on bioretention systems, with reference to Section 3-7-1.

InfraGreen TreeBox HP

Tree needs



Extract – Trees in hard landscaping, Section 3.1.3; Trees & Design Action Group

In order for trees to thrive, they require:

- **Soil** – with sufficient volume and of appropriate composition to encourage tree establishment and growth
- **Aeration** – sufficient root zone ventilation to allow unrestricted access to oxygen and ventilation of carbon dioxide
- **Water** – creating a balance between having a sufficient water supply available, while ensuring water logging of the root environment does not occur through adequate soil drainage
- **Sunlight**

For more information please refer to:
The SuDS Manual (C753), Section 19: Trees.

The desire for mature trees in the city, the shortage of underground space and extreme conditions, were the inspiration for the development of the TreeBox HP.
The system combines high strength concrete supports and cover slabs with plastic wall cells. The TreeBox HP creates a structural wall which sits around the concrete supports.

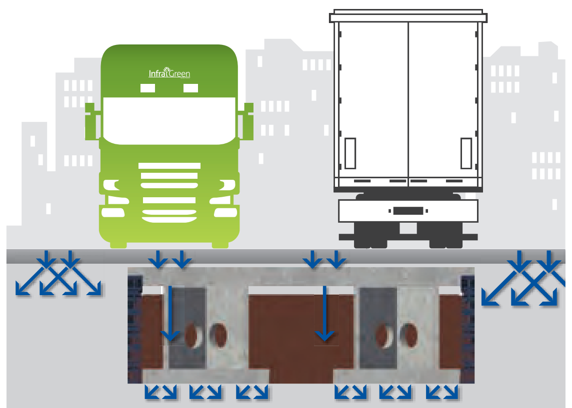
A large void is created which can be filled with soil or tree sand depending on whether the application is for sustainable drainage or just tree growth. The concrete covers provide a load bearing surface which can be overlayed with any hard landscape surfacing material.

Since its introduction during 2003, and after successful trials with the City of Amsterdam, the system has evolved and installation methods have significantly improved.

InfraGreen TreeBox HP System
The TreeBox HP system is one of the most cost-effective solutions to providing high volumes of uncompacted tree soil in urban areas. The result of this is larger trees and even greater benefits when combined with the source control of surface water run-off.

Water and Oxygen transfer through the InfraWeb TRP System

- Promotes large tree growth
- High load capacity
- Suitable for all types of pavements
- Tree roots have perfect growing environment
- Ease of passage and access for services
- Permeable structural walls
- Can form part of a Sustainable Drainage system

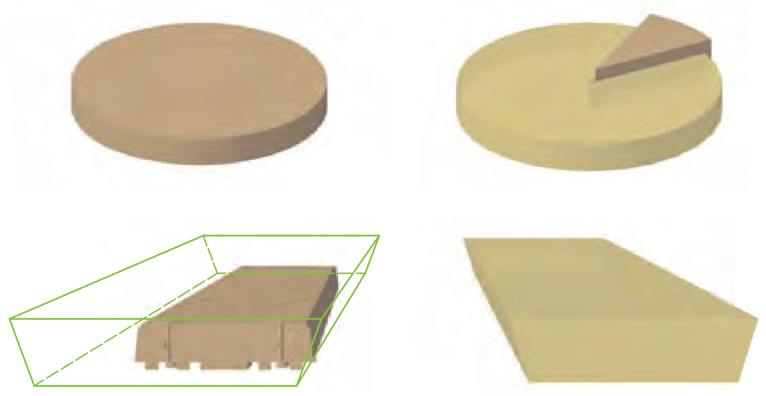


The finished installation provides a perfect habitat for newly planted trees to establish in unnatural environments. The soil remains uncompacted even under the most severe traffic loadings.

3.3.7 Tree ground

The TreeBox HP is suitable for all types of infill soils. Soils rich with minerals, oxygen and beneficial micro-organisms can be used or a bioretention soil with a higher sand content can be used for handling surface water run-off in sustainable drainage applications.

The fertility of the soil can be maintained easily by using the air gap in the top of the installation to feed and water the tree soil periodically. Subject to a favourable ground investigation report, the excavated material may be reused within the TreeBox HP system. This will reduce the total installation cost and the carbon footprint of the installation over traditional planting systems.



The TreeBox HP is designed to be a bespoke solution to a tree planting project. **It is important to select the right tree for its intended site to ensure the tree species selected will survive long term,** based on its specific requirements – i.e. size and level of canopy shade – and that the site isn't restricted in any way by the tree. Every project should be assessed on its own merits and existing soil conditions should be considered.

Modern urbanised towns and cities are increasingly becoming warmer, wetter and less hospitable places to live.

Our technical team are available to provide designers with bespoke solutions. Site specific design advice is part of our service. We recommend thorough site investigations are undertaken on the proposed planting areas to ensure there is sufficient space for the new rooting structure and to assess if the existing soil can form part of the new planting scheme.

Improving and increasing the rooting areas of existing trees in hard landscapes is possible with our TreeBox HP retrofit modules.

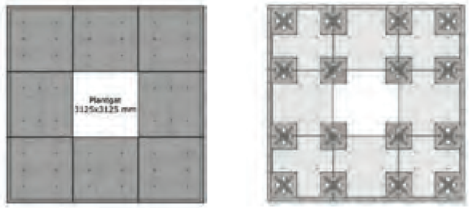
The retrofit units are easy to install and compatible with standard TreeBox HP components. As with the standard system, the retrofit modules can incorporate watering and aeration systems.

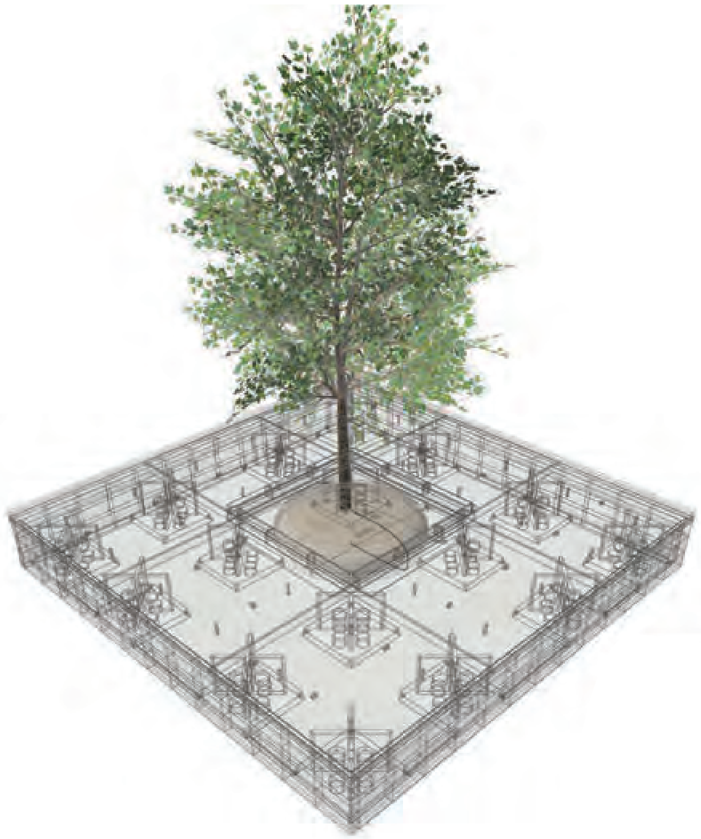
3.3.8 Big trees, big benefits!

The TreeBox HP is the perfect solution for providing large uncompacted volumes of soil for new trees in hard landscapes.

Research and development and many successful installations over the past decade allow performance to be guaranteed for a minimum of 35 years.

Backfill 3125 x 3125mm

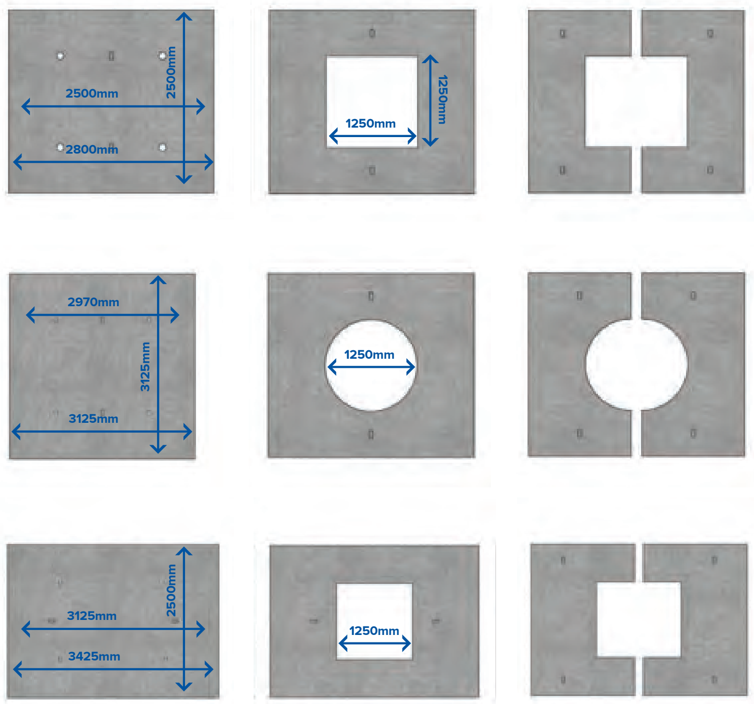


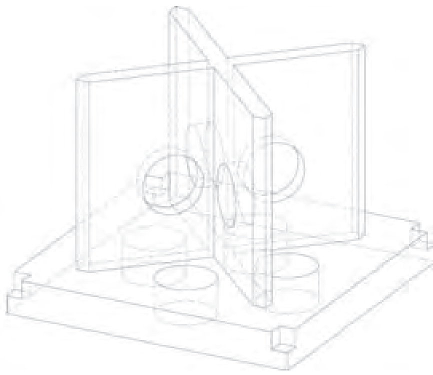


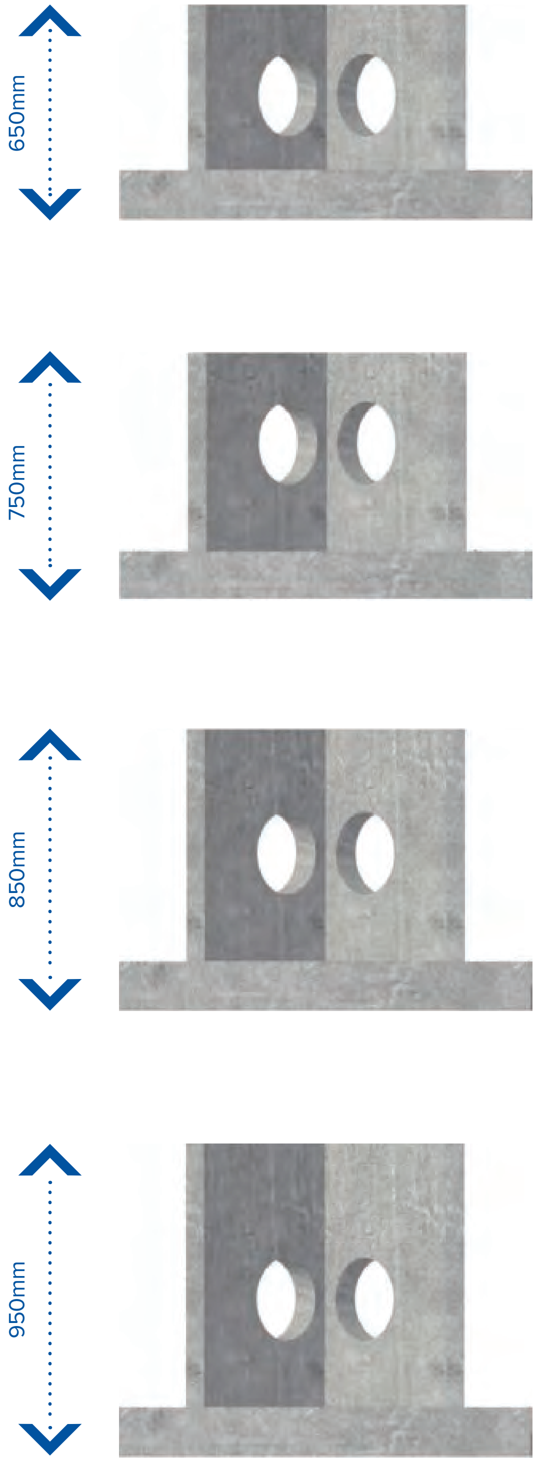
3.3.9 Flexible design

The TreeBox HP system may be used in small planting pits or large continuous trenches to provide rooting space for the trees to grow to their optimum size.

Please contact our Technical Team for site specific advice on 01509 615100.







It should be noted that the life expectancy of new tree planting may be significantly reduced where saturated soil conditions continuously persist around the tree root zone. This could occur within bioretention systems that are regularly inundated with large volumes of surface water run-off, that is retained within the system growing medium for extended periods. Management of additional bioretention vegetation is also important during the establishment of a tree, which may require proactive management for up to three years. This is especially critical during periods of drought; as shallow rooting vegetation will typically survive at the expense of a tree. Careful selection of the tree(s) species is therefore required to ensure it has a tolerance to saturated soil conditions if integration within a bioretention system is proposed. However, even when appropriate tree species tolerant to continuously saturated soil conditions are specified, tree growth should not be expected to thrive. Where the risk of sub-optimum tree growth conditions is identified, consideration should be given to the inclusion of a program of potential managed replanting within the development's maintenance program.

Trees may also be used within raised planters, which still offer benefits to the urban water cycle, in particular the canopy making a valuable contribution toward interception of rainfall. Due to the high water consumption of trees, the establishment of water retention storage within or below the planter may also be utilised for passive irrigation; which can make an additional valuable contribution toward reducing the total annual surface water volume discharged from a development and Section 3.2 (Podium Decks).

Within the context of a development, this section generically subdivides the topic of trees into two forms of installation; maintaining existing trees, retained from the undeveloped site, and new installations specifically designed to contribute towards a developments SuDS design.

3.3.10 Typical construction

A suitable tree species, or combination of species, should be specified to meet the expected development conditions. This may also include defining form and structure (morphological conditions), such as stem girth, tree height, clear stem height and branch structure. It is important that high quality tree stock is sourced, with evidence of good tree health (i.e. plant passport) requested from the supplier, ensuring full traceability.

Standalone tree systems are generally designed to receive surface water run-off from adjacent paved areas. In order to prevent inundation of the tree root system, it has been suggested by CIRIA that paved areas drained to an individual tree installation should be restricted to up to circa 200m^2.

Tree viability and stability requires careful consideration of the root characteristics of proposed tree species, including an assessment of how those characteristics may change as the tree matures.

Consideration therefore needs to be given to the volume of soil available to the tree root system, in addition to access to an appropriate water supply and air availability. Careful specification of the rooting soil is required, to ensure the material has adequate:

- Porosity
- Permeability
- Infiltration rate
- Organic material and nutrient content
- Resistance to over compaction or collapse (e.g. where trafficking may be expected)

within the soil matrix to ensure tree growth is not inhibited and the health of the tree maintained.

Reliable root growth is typically achieved with the following general soil characteristics:

- Rootable soil volume compacted to < 2.5 MN/m^2
- Approx. 45% mineral solids
- 2 – 5% organic content
- ≥ 12% oxygen content
- pH 5.5 – 6.5

It has been suggested that approx. 0.6m^3 of soil is required for every 1.0m^2 of tree canopy area that the proposed tree will be expected to develop at the planned mature tree height; alternatively, depending on the water supply availability, the following approximate tree rootable volumes have been used:

Limited water availability	1.0m^3/year
Water available during the growing season	0.75m^3/year
Readily accessible water supply (uncompacted soil)	0.5m^3/year

With the tree installation establishing a root protection zone equating to circa 5 x the trunk diameter, around the perimeter of the tree base. It should be noted that BS 5837 recommends a root protection zone of 12 x trunk diameter be assumed for existing trees, in the absence of a detailed arboriculture assessment.

An appropriate water supply is required to maintain healthy tree growth, dictated by the proposed tree's expected annual water consumption, which can range from 30 – 175m^3.

The exact water consumption figure depending on the tree species, maturity and season (i.e. growing season); additional seasonal variation in demand would also be influenced by the varying rainfall profile during the year. Mature tree planting therefore, offers the biggest opportunity to reduce total surface water discharge from a development. When used in conjunction with a water retention system that provides passive irrigation, these installations may also enable a development's stormwater attenuation or infiltration volume requirements to be reduced.

Saturation of the tree root system for extended periods of time should also be prevented, with any dedicated water storage provision within the system achieved below the rootable soil volume or above ground via an irrigation system. Water logging of the tree root system induces anaerobic conditions, replacing beneficial aerobic microbial life that increase nutrient availability, with anaerobic bacteria and ultimately cause tree root death. The structural growing media is specified to ensure a sufficient volume of non-compacting rooting soil is available, while establishing a structural framework that is able to accommodate imposed loading. Engineered aggregate or stone mixes are typically used to provide load bearing capacity, particularly beneath pavement areas. With the three main structural growing media classifications being:

- Sand based substrate;
  typically limited to use in untrafficked paved areas, where high compaction levels are not required (compaction typically < 2.5 MN/m^2)
- Medium sized aggregate substrate;
  contains coarse aggregate particles which form a structure that allows a high level of material compaction to be achieved. Typically used within lightly trafficked areas i.e. car park
- Stone skeleton substrate;
  uses larger aggregate particle sizes to provide a higher load bearing capacity, however, it provides a lower volume of rootable soils. Typically used in heavily trafficked areas i.e. HGV or bus (compaction typically > 5.0 MN/m^2)

The majority of tree root growth typically occurs within the upper 1.0m of soil, with significant growth not occurring at depths circa 2.0m.

A number of proprietary products may also be used to provide the structural capacity of aggregate substrates, while offering a higher void ratio that may be infilled with suitable material, or to protect both the tree root system and pavement structural integrity.

Amenity
Tree systems can be designed to easily fit within a development, providing aesthetically appealing green features within an urban environment. Careful selection of the tree species and proposed installation location can offer further environmental benefits through:

- the tree installation; potentially reducing the energy demands in adjacent buildings, that may otherwise be required for
  - cooling; shading of adjacent building(s) offered by a tree canopy, or
  - heating; through the reduction of wind speeds
- cooling of the local microclimate
- shading from the sun, for local community meeting points and adjacent buildings (reducing cooling requirements associated with solar gain)

Biodiversity
In addition to supporting wildlife through the provision of shelter, food and habitat, trees can make a significant contribution to habitat connectivity across a development, offering a method of linking large gaps, which is especially important for animal species that rely on high level tree lines for navigation (i.e. bats).

Careful consideration is therefore required of the tree species' types, planting locations and patterns in order to maximise wildlife benefits. However, in addition to ecological value, resilience should also be considered; ensuring the long term health of the tree installation(s) and the supported wildlife, while minimising future maintenance requirements.

This information has been collated from the following reference material:
- Trees and Design Action Group [TDAG]. (2014) Trees in hard landscape – a guide for delivery. London, UK; TDAG.
- BS 8545:2014, Trees: from nursery to independence in the landscape – Recommendations; London, UK; BSI.
- BS 5837:2012, Trees in relation to design, demolition and construction – Recommendations; London, UK; BSI.
- London Tree Officers Association; Surface materials around trees in hard landscapes; London, UK; Surface materials around trees in hard landscapes Working Party.

3.4 Sports Pitches

The mental and physical health benefits associated with playing sports are endless. Team sports are good for learning accountability, dedication, and leadership. It is important, therefore, to ensure there are facilities available for people of all ages all over the world.

With space at an increasing premium in densely populated urban environments, utilisation of rooftops and brownfield land for sports facilities is on the rise.

Whilst not immediately obvious, sports pitches can represent excellent opportunities for smart drainage solutions whilst delivering high quality amenity and flood alleviation benefits. Flexible in design, with a high-volume ratio and shallow profile, geocellular units are the perfect products for both applications – capturing rainwater at source, storing it for reuse, and with the latest technology of capillary action using the water for pitch irrigation.

Sports pitches and facilities planned with clever water management solutions could help towards reducing the Urban Heat Island effect whilst reducing the strain on sewers and potable water – all whilst maintaining a quality, consistent, all-weather sports surface.

Multifunctional benefits of sports pitches

MAKING SPACE FOR WATER
Enhanced storage capacity by integrating geocellular or pipe solutions.

SURFACE WATER MANAGEMENT
Site level flow control.

PLACEMAKING
Creating attractive green spaces in urban areas that wouldn't usually be available.

EVAPORATIVE COOLING
Large areas of vegetation, such as sports pitch turf, can provide cooling via return of moisture to the air through evaporation/evapotranspiration. Can reduce local temperatures. Can also reflect sunlight.

AMENITY
Enables easy integration into various designs, provides aesthetics, adds water treatment.

HEALTH & WELLBEING
The addition of green spaces can improve wellbeing, help towards a healthier population and introduce leisure facilities such as sports pitches to encourage a less sedentary lifestyle.

ASSET CREATION
Addition of gardens/green spaces can increase the aesthetic look of an area adding value to the property.

3.4.1 Polypipe GI – hydraulic benefits

Sports pitches with a Permavoid sub-base are effective at offering the following water management benefits:

Zero pitch discharge rate achievable

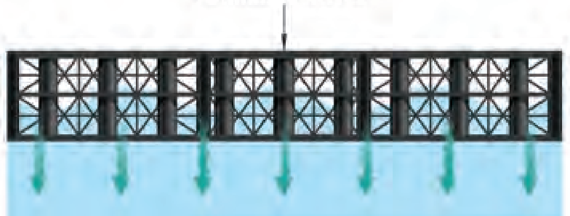
Due to the large surface area of the shallow Permavoid layer, infiltration is incredibly efficient, making the sports construction a zero-discharge facility, even when soil percolation rates are very low.

Able to replicate the green field run-off rate

A requirement of all the current SuDS legislation and best practice guidance.

Reducing the need for sprinklers

Implementing a passive irrigation system to feed the pitch from below, negates the need for pop-up sprinkler systems and could provide water savings by as much as 60%.[2]



Polypipe GI – shallow construction

Shallow attenuation

As the sub-base layer has a 95% void ratio and only 150mm or 85mm in depth, the drainage system can efficiently drain water from the surface even in a 1 in 100 year storm event, without flooding. This is because the 85mm sub-base option can hold up to 80mm of water across the entire construction, which equates to over 450,000 litres of storage per standard $6,000m^2$ pitch construction.

Shallow infiltration

As the attenuation volume is shallow and spread over a large surface area, infiltration is extremely fast and efficient. This also makes it possible to infiltrate where deeper systems can't when high water tables are encountered.

Shallow drainage

Ideal for linking to swales, basins and ponds without the need for a deep lagoon and the associated health and safety precautions.

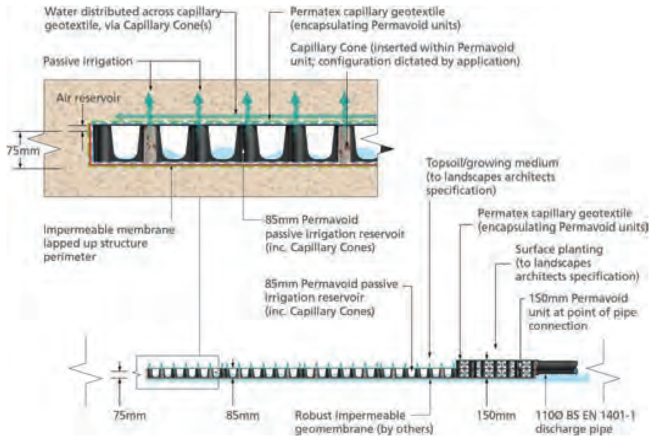
Polypipe GI Product Guide		
Product	**Description**	**Code**
Permavoid 85 &150	Sub-base replacement: providing significantly higher storage capacity, compared with an equivalent depth of granular sub-base material.	PVPP85 PVPP150
Permavoid^2 85	Comprises of six pre-connected units and is designed to provide attenuation for shallow non-loaded applications. Ideal for use in the most diverse roof and podium deck applications, alongside hard-landscaping.	PVPP85RX6
Permavoid Capillary Cones	Enabling passive irrigation via capillary action, for use on roof gardens, green roofs, sports pitches and arenas.	PVPP85CC2 PVPP85CC4
Permatex 300 Geotextile	A heavy duty, non-woven, needle punched, polypropylene geotextile designed to protect and separate Permavoid geocellular layers.	PV23006
Permatex Capillary Geotextile	A heavy-duty, non-woven, needle-punched geotextile made from a blend of modified polyester fibres. It is specially formulated to absorb water used to irrigate mineral substrates when used in conjunction with Permavoid units.	PV23008 PV23009
Permaties	A Patented tapered tie that interlocks the Permavoid cells into a secure and consistent raft.	PVCLIP

2. Water is our playground brochure. BLUE@GREEN by SWDsystems. http://www.swdsystems.com/producten/blue2green/

Polypipe GI – passive irrigation and reuse

Rainwater storage facility

With the addition of an impermeable membrane, it is possible to store rainwater within the pitch sub-base. This is a fantastic space-saving scheme without compromising on the storage volume. Clever arrangements of outlet devices can allow the combination of storage for reuse and attenuation for storm events.



Passive irrigation

The innovative capillary action technology passively irrigates the sports surface 24 hours a day. This is due to the nature of the Permavoid Capillary Cones, which naturally transport water along a concentration gradient – both vertically and horizontally – until the surface above achieves the optimum moisture content. The capillary cone technology also works in reverse to improve the drainage aspects of the surface by pulling excess water from a zone of high concentration. This system only provides water as required 'on demand', avoiding over-irrigation.

The benefits of using sports facilities incorporating Permavoid include:

Lighter in weight construction

- Reduces differential settlement
- Ideal for abnormal ground conditions
- Lower California Bearing Ratio (CBR) required at formation
- No nett surcharge – the total weight of the constructed system is no greater than the excavated soils
- Tree root zone protection for sports facilities in proximity of trees, by reducing compaction and increasing aeration of the soil

Consistency

- Consistent factory manufactured sub-base
- No variability in sub-base compaction
- Cost certainty – aggregate sub-base price often fluctuates depending on location

Sustainability

- Light-in-weight, interlocking nature means the system is ideal for temporary events
- Recycled material, recyclable, and reusable
- Minimises need for quarried aggregate – reduced carbon footprint
- Eliminates the need for macadam layer

Cost-effectiveness

- Reduced excavation
- Fast installation in accordance with Construction Design and Management (CDM) regulations

3.4.2 Typical construction

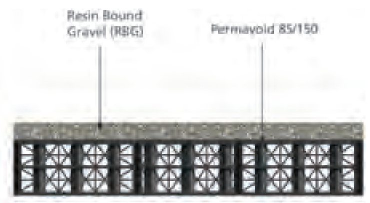
Surface consistency and drainage of a sports facility is perhaps the most important consideration throughout design and construction.

As a result, a wide range of sports facility designs have been developed that incorporate the Permavoid geocellular units. These geocellular units provide a consistent sub-base allowing water to freely drain from the surface, ideal for sports facilities.

Surfacing

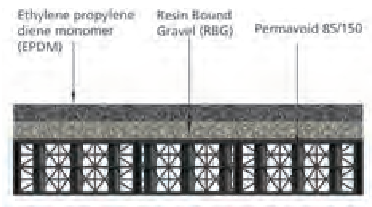
The beauty of using Permavoid in sports is the versatility it provides. There are many different types of sports surfaces that can be constructed directly onto the Permavoid sub-base.

Careful considerations are required when designing a sports facility, as different sports have specific requirements that the construction must comply with, such as slip resistance, rebound, shock absorption and moisture content. Below are five examples of regularly used surfaces.



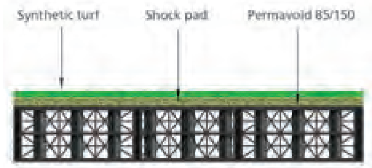
1: Resin Bound Gravel (RBG)

As an alternative to a traditional macadam surface, RBG can produce the same durability, robustness and hardness of macadam, whilst remaining fast and easy to install in logistically challenging areas. A popular surface for Multi Use Games Areas (MUGAs) as these characteristics maximise ball bounce, perfect for sports such as tennis and basketball. RBG surfacing has been independently tested to Sport England Guidelines for slip resistance and permeability.



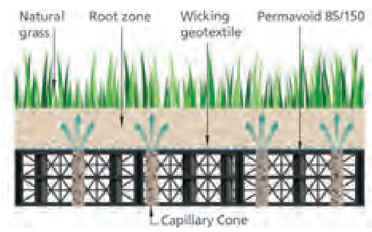
2: Polymeric Surface

Recognised and recommended by Sport England as the chosen surface for running tracks, compliant with IAAF standards. Typically, RBG is installed directly on the Permavoid sub-base, followed by the wet-poured ethylene propylene diene monomer (EPDM) surface, sometimes referred to as synthetic rubber.



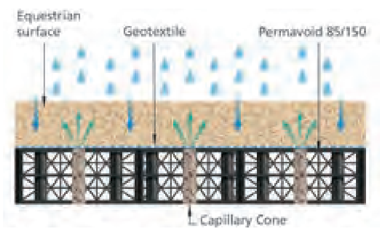
3: Synthetic Turf

Perhaps the most popular surface used in modern sports facilities. There is an extensive range of synthetic turf available, with each turf suited for a specific purpose. A shockpad can be installed directly onto Permavoid followed by the synthetic turf of choice. This surface supports a wide range of sports including, football, rugby, hockey, and tennis.



4: Natural Grass

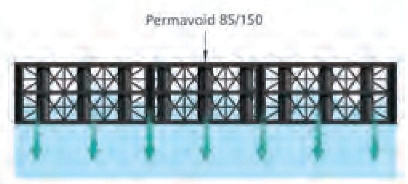
A very simple but effective construction, with endless sporting uses. The natural grass can be installed directly onto Permavoid with a root zone. This creates a well-drained natural grass surface, usable all year round.



5: Equestrian Sand Surface

In Equestrian sport, the moisture content of the sand fibre surface is critical. The ability to install equestrian surfacing directly onto Permavoid allows the surface to be well-irrigated, maintaining the optimum moisture content without flooding.

Permavoid geocellular unit

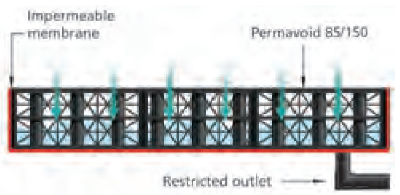


Drainage

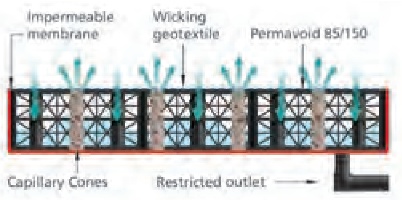
There are a number of ways in which the Permavoid drainage can be utilised in sports, to give the best possible sports surface combined with extremely efficient water drainage techniques.

Full bed drainage – soakaway

The most simple sports constructions comprise a single layer raft of 150mm or 85mm Permavoid units. This creates a high capacity voided sub-base which actively disperses surface water evenly before draining naturally into the ground. This type of sub-base drainage supports all sports surfaces mentioned previously, whilst offering incredibly efficient infiltration.



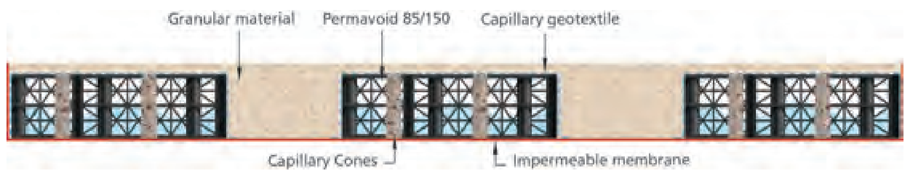
The addition of an impermeable membrane and restricted outlet allows the Permavoid sub-base to capture and retain large quantities of water within a shallow pitch construction. This can be used for rainwater attenuation or rainwater reuse, as the 85mm Permavoid cells have the capacity to store up to 80mm of water across the entire construction. This type of sub-base can be used for all sports surfaces.



The most advanced sports drainage system is the Permavoid 85mm blanket with the innovative capillary action technology. Capillary Cones and geotextiles actively transport water evenly across a concentration gradient vertically and horizontally. This means the water captured in the Permavoid sub-base is used to passively irrigate the sports surface, creating an all-weather, self-conditioning sports facility. This type of sub-base drainage is ideal for equestrian and natural grass sports where irrigation and moisture content is critical.

Strip drainage

It is also possible to produce a conventional/sports drainage solution where appropriate. This is achieved by installing Permavoid in linear strips at calculated centres, the intervening gaps between Permavoid units infilled with granular material.



3.4.3 Water treatment

The surfacing of a sports facility acts as a large-scale filter, preventing debris entering the drainage system. This is the first stage of the water purification process.

As the rainwater collection system is confined within the pitch construction, the stored water is enclosed and used for capillary irrigation from below; eliminating the need for above ground spray systems, thereby reducing the risk associated with airborne pathogens.

Water stored within the sports construction is constantly moving, whether it is naturally soaking away, or flowing through the restricted outlet for drainage or reuse. This prevents the water becoming stagnant, which reduces the risk of mosquito breeding.

3.4.4 Amenity

With sports, the facility itself is the primary amenity which can be utilised to create effective sustainable drainage – and improve existing drainage.

Natural grass sports facilities are known to have a cooling effect on the surrounding environment. This is caused by transpiration, which is the evaporation of water from the grass leaves. Evaporation uses the surrounding energy to transfer state of matter from liquid to gas, it is this process that causes the actual cooling effect on the environment. Equestrian surfaces have the same cooling effect, as moisture trapped in the sand fibre surface evaporates.

Research has shown that in hot and dry climates, synthetic turf pitches can be up to 30°C hotter than a natural grass surface. This is proving to be an issue as the sports facility becomes unusable due to the heat transfer to the sole, causing discomfort and dehydration. Sports facilities incorporating the Permavoid capillary system have the ability to maintain a moist synthetic turf surface, which can evaporate, giving off the same cooling effect observed with natural grass and equestrian facilities.

3.5 Cycle Paths

Cycle paths are components of infrastructure that are designed to facilitate the safe passage of cyclists. Within an urban environment, new cycle paths are typically designed to segregate cyclists from other road traffic, with the aim of increasing safety and encouraging the wider use of this mode of transport.

Cycle paths may be generally classified as either new dedicated path construction, designed at the outset for cyclist and pedestrian use, or the repurposing of existing pavements.

This includes whether it is repurposing part of the road carriageway itself, adjacent footpath(s), or areas that run parallel with the roadway. The construction of cycle paths offers an ideal opportunity to incorporate SuDS elements, especially when retro-fitting within an urban environment and deal with the surface water at source.

Multifunctional benefits of cycle paths

MAKING SPACE FOR WATER
Modular high void ratio, high strength geocellular units.

SURFACE WATER MANAGEMENT
Flow control at source.

WATER QUALITY
Offers opportunities to treat water via Permeable Paving aggregate and proprietary components such as treatment geotextiles.

HEALTH & WELLBEING
Ponds or Wetlands that are accessible or overlooked can increase mental wellbeing.

AMENITY
Facilitates ease of transport links within new and existing developments.

ASSET CREATION
Dependent on location of development can increase tourism and healthy transport links.

3.5.1 Cycle path enhancement

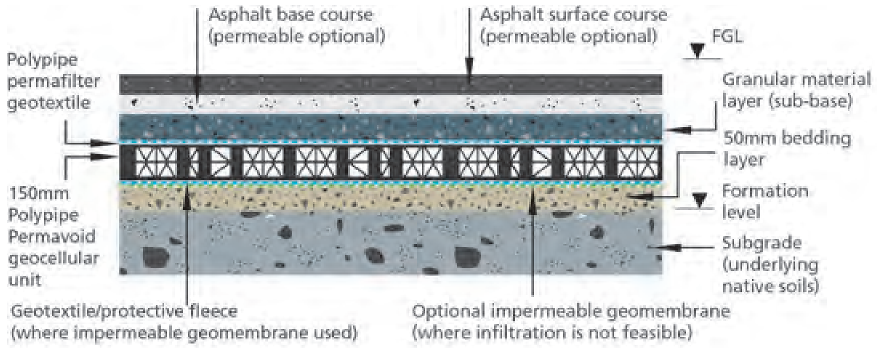
Polypipe is able to offer a number of products that may be used to enhance the water management capability of cycle paths and to protect the root zone of trees and shrubs adjacent to new cycle path construction.

Where the Polypipe Permavoid unit is incorporated in to the cycle path construction, it may be constructed:

- As an attenuation or infiltration system (may include an appropriate geosynthetic root barrier), the Permavoid unit effectively creates an air void within the pavement; discouraging root growth within the pavement, but can also be used to ensure penetration of moisture and air into the root area
- With an infill of a suitable growth medium, the Permavoid system ensures this soil does not become compacted, allowing room for future root growth while facilitating the penetration of moisture and air

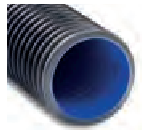
Surface water management

Significant surface water management benefits may be gained from cycle paths if they are constructed following the same principles as a permeable pavement. Increasing the potential attenuation storage provided within the granular sub-base material can be achieved through the substitution of sub-base material with units from Polypipe's Permavoid product range.



The Permavoid system forms a unique high strength structural raft, complying with the British Standard design guidance for permeable pavements constructed from engineered and natural pavers (BS 7533-13:2009).

Where a partial or no infiltration pavement is installed, the inclusion of a perforated pipe system at the pavement formation level may be required to ensure the efficient drainage of the sub-base material. Polypipe is able to offer the following product range which can be used for this application:



Ridgidrain

Thermoplastic structured walled surface water drainage system. Available as carrier, half perforated and fully perforated pipe in diameters from 100 – 900mm. The range also includes a comprehensive selection of fittings to allow simple integration into the drainage system, available in 6m and lighter in weight than rigid materials. BBA HAPAS approved for use in the collection and disposal of surface and sub-surface water in highway drainage.

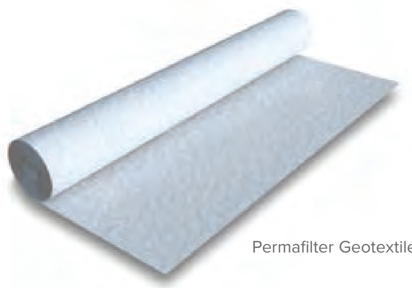
Treatment benefits

Where a geotextile layer is used within a permeable pavement construction, Polypipe is able to offer our proprietary Permafilter geotextile, which is specifically designed to treat hydrocarbons within surface water flows.

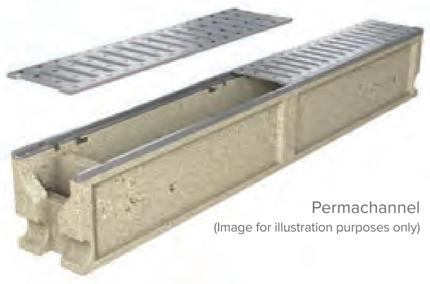
Permafilter is a dimpled non-woven needle punched geotextile, comprising a proprietary blend of hydrophilic and hydrophobic fibres. The proprietary blend of fibres is designed to retain hydrocarbons on the geotextile; in addition to maintaining a level of moisture that encourages biofilm formation, and subsequent aerobic biodegradation of the retained hydrocarbons.

A permeable pavement, incorporating a Permavoid sub-base replacement installation, effectively treats 100% of the surface water that flows through the system and has been shown to outperform Class 1 and Class 2 separators (as defined within Pollution Prevention Guidelines (PPG3)).

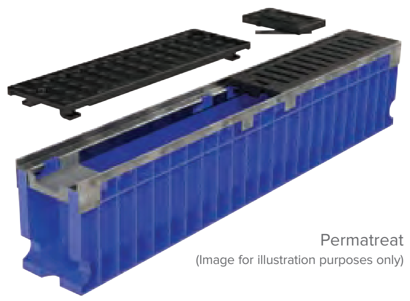
If multiple inlets are required to be introduced into a path's sub-base (i.e. sump outlets from an adjacent linear Permachannel installation) a narrow row of Permavoid Biomat units may be used to increase the water treatment offered by the system, prior to its distribution within the permeable pavement's sub-base. The Permavoid Biomat unit incorporates a floating oil treatment geotextile, which is designed to intercept and encourage the biodegradation of excess oils and hydrocarbons, prior to them being discharged into the system.



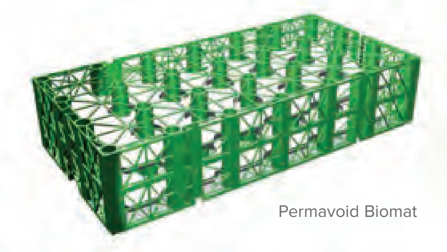
Permafilter Geotextile



Permachannel
(Image for illustration purposes only)



Permatreat
(Image for illustration purposes only)



Permavoid Biomat

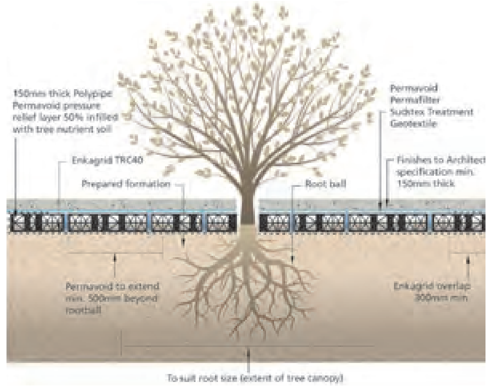
Root zone protection

Installation of a Permavoid sub-base replacement system within the pavement construction can be used to facilitate the protection of root zones.

Through the unique way that the Permavoid system is jointed, an installation of Permavoid geocellular units effectively form a load bearing structural raft. This is able to offer the benefits of:

- Protecting root zones by preventing the over compaction of the soils through the distribution of loading imposed by trafficking
- Facilitating the penetration of moisture and air into the rooting area
- Reducing the detrimental effect of differential soil movements if the sub-grade (supporting native soils) is susceptible to changes in soil moisture i.e. shrinkage and heave

It should be noted that if a Permavoid irrigation system is used, it could support planting adjacent to the cycle path system.



Polypipe is able to offer a range of pre-fabricated chambers, designed to facilitate the simple inclusion of a range of flow controls in the drainage system.

Cycle Path Product Application		
Product	**Description**	**Code**
Polystorm	May be used to disperse water from point inlets within the pavement sub-base.	PSM1A
Permavoid	Sub-base replacement: providing significantly higher storage capacity, compared with an equivalent depth of granular sub-base material.	PVPP85 PVPP150
Permavoid Rainwater Diffuser Unit	Used to disperse surface water from point inlets, where discharged within the sub-base.	PV09011
Permavoid Biomat	Incorporated within a Permavoid structure, typically restricted to the location of point inlets, to provide additional hydrocarbon treatment.	PV150BM
Permafoam	An open celled absorbent phenolic foam incorporated into Permavoid geocellular units for 'on demand' irrigation or check dams.	PVPP85PF PVPP150PF
Permachannel	Collection of surface water run-off from an impermeable pavement surface, includes elements that provide a high strength of initial water treatment.	PV03001
Permafilter	Proprietary geotextile designed to offer enhanced hydrocarbon pollution treatment, typically installed beneath the surface layer(s).	PV23002
Geomembrane	May be used to form check dams within the permeable pavement construction, limiting loss of attenuation storage, within developments containing steep gradients.	-
Permatex 300 Geotextile	A heavy duty, non-woven, needle punched, polypropylene geotextile designed to protect and separate Permavoid geocellular layers.	PV23006
Permatreat	Available in two grating options, Permatreat is a versatile, linear treatment system that can provide source control and pollution treatment in a wide variety of locations and applications.	-
Ridgidrain	A high strength HDPE surface water drainage piping system, used for surface and sub-surface drainage applications, available in sizes from 100-900mm diameter.	RD100X6PE
Slimblock	A high strength modular paving system manufactured from recycled plastic, which can be infilled with grass or with gravel depending upon the aesthetic requirements.	PP50SBB PP50SBG
Flowblock	A high strength, modular permeable paving and grass protection system, for heavy duty applications such as HGV access and intensively trafficked areas.	PP75FBB PP75FBG
GS Pro	GS Pro Plastic Paving Panels are manufactured from high-quality polypropylene. The GS Pro has double cell walls, to provide extra strength, and also has a unique panel connection system which limits both horizontal and vertical expansion.	PP35GSPB PP35GSPG
Capillary Geotextile	A heavy-duty, non-woven, needle-punched geotextile made from a blend of modified polyester fibres. It is specially formulated to absorb water used to irrigate mineral substrates when used in conjunction with Permavoid units.	PV23008

3.5.2 Typical construction

The construction of a proposed cycle path may vary significantly, depending on whether it is essentially a new dedicated construction, or re-purposing of existing paved areas.

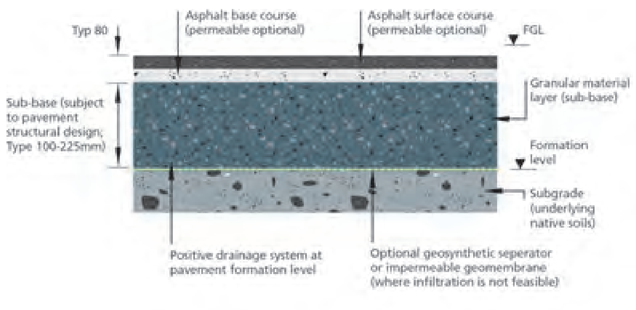
Modification of existing paved areas may also involve a wide range of works, from the installation of intermediate traffic barriers and placement of surface markings, to the excavation and installation of dedicated pavement and kerbing. A typical new cycle path consists of a linear section of pavement, with the following typical minimum acceptable widths, within:

- Road carriageway (vehicle traffic) 1.5-2.0m
- Path (shared with pedestrians) 2.5-3.0m
- Dedicated cycle path
  - Single direction flow 1.5-2.0m
  - Two directional flow 2.5-4.0m

Typically consisting of:

- Surface layer(s), dictated by pavement type.
- Structural base, (i.e. granular material).
- Optional – geosynthetic separator at interface of structural base and unmodified founding native soils (subgrade).

Where the cycle path forms part of the road carriageway, the design of the road and footpath pavement would be required to follow standard highway design guidance.



3.5.3 New construction

Where the proposed path construction passes over the root zone of trees or shrubs that are to be retained, protective measures would typically be required to both protect the health of the adjacent planting and limit the potential damage that future vegetation growth may have on the pavement's structural integrity.

This may be achieved through the creation of a reinforced raft, either within the pavement construction or immediately below, to distribute any traffic loading thereby limiting the risk of the underlying soils becoming over compacted, in addition to allowing moisture and air to still penetrate the root area.

3.5.4 Retro-fit

Where a proposed cycle path involves the repurposing of existing pavement areas, in particular where significant changes to the pavement construction are proposed, it offers an ideal opportunity to consider the inclusion of features that are able to offer significant water management benefits.

However, due to the primary purpose of a cycle path, the biggest gain would be obtained by constructing the cycle path using the principles of permeable pavement design. It should be noted that where the path runs close to planting, shedding of vegetation or shading that encourage the growth of moss etc. may cause premature clogging of a porous surfacing. In which case the use of a macro permeable pavement construction should be considered in these areas, requiring the installation of kerb or channel drainage units.

The use of a geocellular sub-base replacement system would minimise the level of disruption, namely the depth of excavation required; while offering the greatest gains in additional attenuation storage capacity provision. If adjacent planting has caused damage to the existing pavement, as with new cycle path construction, remedial measures that may be considered include the installation of an appropriate geosynthetic root barrier or the creation of a flexible load bearing raft, to either discourage root growth within a reinstated pavement or allow for future potential growth and minimise the potential remedial works that may subsequently be required.

3.5.5 Water treatment

If constructed as a permeable pavement, a cycle path would typically be viewed as being able to offer a significant benefit with respect to improving water quality.

For more information on adding water treatment to cycle paths, please see the Permeable Paving section on page 162.

3.5.6 Hydraulic benefits

While cycle paths are primarily utilised to facilitate the passage of cyclists and pedestrians, if constructed in a similar manner to a permeable pavement (refer to Section 3-6), they are able to offer the following hydraulic benefits:

- Interception; reducing the volume of surface water that may need to be discharged from the development. Research demonstrates that rainfall up to 5mm does not typically cause a discharge from permeable pavements, due to:
  - Attenuation within the permeable material forming the pavement, and surface evaporation
- Can be effective in relieving the build-up of excess surface water, which ordinarily could lead to flooding
- Infiltration; reducing the volume of surface water that may need to be discharged from the development, through infiltration into the underlying soils, where feasible
- Surface water attenuation storage capacity within the sub-base layer
- Minimising the rate of surface water discharge into the drainage system, as flow rates through permeable pavements tend to be significantly slower compared with other drainage systems, as water has to percolate through the pavement structure

Cycle paths may also be designed to act as exceedance flow paths, offering greater flexibility to a designer in directing flow direction than a road carriageway; however, the typical smaller cross section will offer a lower safe flow capacity.

Permeable pavements are able to accommodate surface water run-off from adjacent impermeable areas, either by surface flows crossing a permeable pavement surface, or via dedicated inlets within the pavement sub-base. As a rule of thumb, an impermeable to permeable pavement area ratio of 2:1, can typically be accommodated within a permeable pavement without the need for excessive increases in sub-base depth.

3.6 Permeable Pavements

A permeable pavement is one that is designed to allow surface water to percolate through the pavement surface and underlying structural layers. These pavements are generally categorised into one of three classifications according to how surface water is managed within the system; the classifications being:

Total infiltration (Type A)

Where the percolation rate of the underlying formation soils (subgrade) is sufficient to infiltrate all of the water that falls onto the pavement.

Partial infiltration (Type B)

Used in situations where the subgrade is unable to infiltrate all of the water falling onto the pavement. A positive drainage system is typically installed at the formation layer to collect excess surface water, prior to it being discharged from the system into a downstream drainage system.

No infiltration (Type C)

Typically installed with an impermeable geomembrane liner around the pavement construction to retain surface water within the system. This system type is generally used where infiltration is not feasible, the load bearing capacity of the subgrade would be adversely affected, or where water retention is desired. The retained water may then be used to facilitate rainwater harvesting or provide stormwater attenuation capacity within the developments SuDS drainage design.

Permeable pavements can be used on most sites, where they are typically installed as a direct alternative to impermeable surfaces. Therefore, permeable pavements are able to offer numerous benefits, without requiring any additional space above what would typically be required by the development. However, their use in areas that are expected to receive high silt loads should be avoided, due to the risk of premature clogging of the pavement surfacing.

There are numerous options for the type of permeable surfacing that may be used, a number of which are summarised on page 164.

Permeable pavements

If a pavement is formed using impermeable material; such as block pavers (without spacers), its permeability properties are characterised by a discontinuity – or a gap – for the water to find a way through to the soil or receptacle below.

Porous pavements

Where the pavement is formed from a material that is inherently permeable across the entire surface

- Permeable asphalt
- Permeable concrete
- Resin bound gravel
- Gravel surface
- Reinforced grass
- Sport area surfaces
- Plastic Permeable Paving

It should be noted that even where a permeable pavement surface is not used, the sub-base material beneath an impermeable surface may still be used to provide surface water storage. Generically termed macro permeable systems, surface water run-off is typically collected by a linear perimeter system (i.e. Permachannel) prior to discharge into the sub-base granular material. Careful consideration of the initial treatment requirements of the collected surface water is required. Along with an assessment of the hydraulic capacity of the sub-base connections, including their ability to disperse or collect water within the sub-base material.

(SuDS Manual (C753) guidance – Chapter 20)

Indicative Treatment Efficiency

Pollutant mitigation indices	Reduction: Inlet to Outlet
Metals	0.7
Suspended Solids	0.6
Hydrocarbons	0.7

CIRIA C753; Table 26.3

Permeable pavement systems are typically used in areas (i.e. car parking areas), where the risk of being subjected to catastrophic spillages is extremely low. In these situations, permeable pavements have been shown to be highly effective at dealing with localised and relatively low level pollution (e.g. leaking vehicle engine).

Multifunctional benefits of permeable pavements

MAKING SPACE FOR WATER
Modular high void ratio, high strength geocellular units providing a BS7533-19:2009 compliant system while minimising construction depths.

PLACEMAKING
Incorporating decorative hard landscaping designs with green infrastructure offers opportunities to enhance or minimise the visual impact of the surface areas through the choice of surfacing materials.

SURFACE WATER MANAGEMENT
Flow control at source.

WATER QUALITY
Offers opportunities to treat water via Permeable Paving aggregate and proprietary components such as treatment geotextiles.

AMENITY
Incorporating decorative hard landscaping designs with green infrastructure offers opportunities to enhance or minimise the visual impact of the surface areas through the choice of surfacing materials.

ASSET CREATION
Addition of decorative paving can increase the aesthetic look of an area adding value to the property.

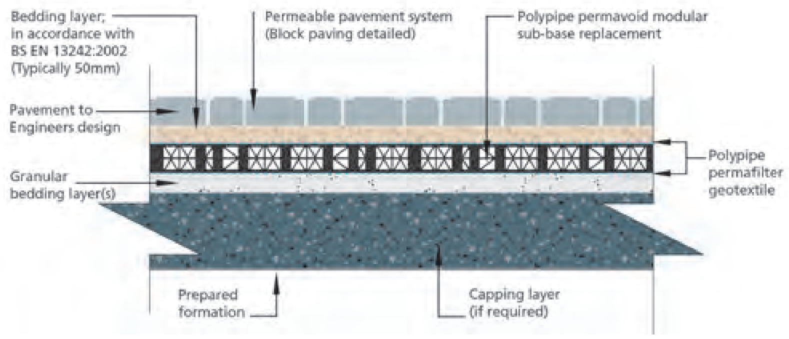
3.6.1 Increasing storage in permeable pavements - hydraulic benefits

Additional attenuation storage capacity may be provided within the pavement construction by substitution of the sub-base material with Permavoid units, offering additional attenuation storage benefits, due to the unit's significantly higher porosity. The Permavoid unit having a nominal porosity of 95%, compared with a typically assumed granular sub-base material porosity of 30%.

The Permavoid system forms a unique high strength structural raft, complying with the British Standard (BS 7533-13:2009) design guidance for permeable pavements constructed from engineered and natural pavers.

Geocellular units can also behave as a conduit, provided a continuous installation is maintained across the pavement cross section, with flows typically driven by hydraulic head. This form of construction may also be used with pavement gradients steeper than 3%, provided appropriate check dams are created within the structure.

These check dams may be formed through the creation of geomembrane barriers, in addition to the optional use of geofoam units as an effective flow control. Geocellular units have a uniform shape and high porosity, in addition to offering a higher flow resistance than conventional pipe systems, which would further slow the flow of water through the system.



Typical examples of various permeable pavement system construction, modified to incorporate a layer of Permavoid units, are given below. **It should be noted that the pavement and Permavoid construction is subject to a site-specific geotechnical and structural assessment to ensure it is suitable for the proposed development.**

Where a partial or no infiltration pavement is installed, the inclusion of a perforated pipe system at the pavement formation level may be required to ensure the efficient drainage of the sub-base material. Polypipe is able to offer Ridgidrain, Landcoil, Filter Drain, Permatreat and Ridgitreat for this application:

Polypipe Products			
Product	**Description**	**Length m**	**Code**
Ridgidrain	A high strength HDPE surface water drainage piping system, used for surface and sub-surface drainage applications, available in sizes from 150-900mm diameter.	1.5 - 6	RD150X6PE
Permavoid	Geocellular sub-base replacement system that locks together to form an interlocking raft of exceptional high compressive and tensile strength.	0.708	PVPP85 PVPP150
Ridgitreat	A perforated HDPE Ridgidrain structured wall surface water drainage pipe, wrapped in Permafilter Geotextile, supplied plain ended in pipe diameters: 100mm, 150mm, 225mm and 300mm.	6	RDT100X6PEP
Landcoil	A land drainage system for the management of excess land waste, a full range of pipes and fittings available in sizes 60-200mm. Perforated and unperforated options available.	25 - 40	LD6025

3.6.2 Treatment benefits

Where a geotextile layer is used within the system construction, Polypipe is able to offer our proprietary Permafilter geotextile, which is specifically designed to treat hydrocarbons within surface water flows. Permafilter is a dimpled non-woven needle punched geotextile, comprising a proprietary blend of hydrophilic and hydrophobic fibres. The proprietary blend of fibres is designed to retain hydrocarbons on the geotextile in addition to maintaining a level of moisture that encourages biofilm formation and subsequent aerobic biodegradation of the retained hydrocarbons.

A permeable pavement incorporating a Permavoid sub-base replacement installation, effectively treats 100% of the surface water that flows through the system and has been shown to outperform Class 1 and Class 2 separators (as defined within Pollution Prevention Guidelines 3).

Polypipe is able to offer a number of geosynthetic and ancillary products that can be used with permeable pavement construction.

Where a point inlet is introduced into a pavement sub-base, Permavoid Diffuser units are available. The geotextile pre-encapsulated units treat and disperse the water into the sub-base.

Road/Yard Gully

Where a Road or Yard gully is fitted, Permaceptor encapsulated in impermeable Geomembrane and Geotextile fleece can be fitted post-gully to treat the water; removing silt and oil contaminants before discharging the water downstream.

Permachannel and Biomat

Where there are linear multiple inlets (i.e. Permachannel sump outlets) a narrow row of Permavoid or Polystorm units may be used to receive the collected surface water and distribute it into the granular sub-base or separate adjacent infiltration/attenuation system. Again, in this instance the geocellular installation may include the use of Permavoid Biomat to increase the water treatment offered by the system.

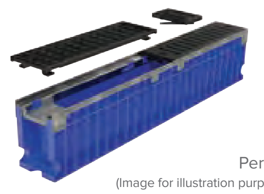

Permafilter Geotextile


Permavoid Rainwater Diffuser Unit


Permaceptor


Permavoid Biomat


Permachannel
(Image for illustration purposes only)


Permatreat
(Image for illustration purposes only)

Polypipe Products			
Product	**Description**	**Length m**	**Code**
Permafilter	A non-woven, dimpled, needle - punched geotextile designed for hydrocarbon pollution treatment.	100	PV09011
Permavoid Rainwater Diffuser Unit	Permavoid units encapsulated with a 2mm mesh fabric diffuse the collected run-off into the surrounding granular sub-base.	0.708	PV09011
Permaceptor	A combined run-off collection, silt/oil interceptor and treatment system used with road/yard gullies.	0.708	PV04002
Permachannel	A linear treatment system that combines run-off collection, silt and effluent interception and water treatment functions.	1	PV03001
Permatreat	Available in two grating options, Permatreat is a versatile, linear treatment system that can provide source control and pollution treatment in a wide variety of locations and applications.	1	PVTEA/ PVTS
Flowblock	A high strength, modular permeable paving and grass protection system, for heavy duty applications such as HGV access and intensively trafficked areas.	0.5 x 0.5	PP75FBB PP75FBG
Slimblock	A high strength modular paving system manufactured from recycled plastic, which can be infilled with grass or with gravel depending upon the aesthetic requirements.	0.5 x 0.5	PP50SBB PP50SBG
Permavoid Biomat	High strength geocellular unit containing a low density, oil treating, geosynthetic floating mat.	0.708	PV150BM
Ridgigully	Blow moulded and manufactured from HDPE suitable for both trapped and untrapped systems, available in 2 depths of 750mm or 900mm.	N/A	RG450750 RG450900

Improved maintenance and inspection

Polypipe is able to offer a comprehensive range of pre-fabricated chambers, designed to facilitate the simple inclusion of a range of flow controls in the drainage system. Enabling the attenuation storage capacity offered by permeable pavement systems to be fully utilised.

3.6.3 Amenity benefits

Incorporating geocellular units within the sub-base, significantly increases the attenuation storage capacity within the drainage system, without an increased requirement for space within the development. This can both facilitate the application of SuDS within a development, in addition to offering the designer more flexibility in increasing the spaces with amenity value.

RIDGISTORMCheck Vortex Flow Control

RIDGISTORMCheck Orifice Flow Control

3.6.4 Biodiversity benefits

As with amenity benefits, Polypipe system enhancements would not directly increase the biodiversity benefits of permeable systems – except to significantly increase the attenuation storage capacity that is offered by a proposed permeable pavement, without an increased requirement for space within the development. This can offer Designers more flexibility in increasing the spaces within the development that are able to offer biodiversity benefits.

3.6.5 Conventional SuDS - typical construction

The design of permeable pavements may be split into two inter-related considerations, these being:

Structural

The depth of the pavement structural layers is first determined through an analysis of the type and frequency of vehicle trafficking that may be expected during the pavement's design life, in conjunction with an assessment of the load bearing capacity of the native soils. This methodology is similar to non-permeable pavement design; the exception being the specification of the pavement structural layers, which should ensure that the vertical or horizontal passage of water through the pavement is not inhibited.

(Structural design guidance – Section 20.9 SuDS Manual (C753) guidance)

Hydraulic

The available depth of granular sub-base material capable of storing surface water is assessed. This is to ensure there is sufficient storage capacity within the pavement structure to accommodate the water flowing through the surface from the assumed design rainstorm event. Where additional storage requirements are identified within the drainage design, the sub-base material depth may be increased (above the minimum structural requirement).

(Hydraulic design guidance – Section 20.5 SuDS Manual (C753) guidance)

For more information please refer to:
The SuDS Manual (C753), Section 20: Permeable Pavements.

Pavement construction generally consists of a number of distinct layers, summarised below. Unlike non-permeable pavements, permeable pavements also require consideration to be given to the permeability of the materials used in their construction:

- Surface layer(s), dictated by the pavement type typical minimum surface infiltration capacity – 6.94x10-5 m/s (250 mm/h)
- Structural base, if required (e.g. hydraulic or bitumen bound granular material)
- Permeable sub-base (coarse graded granular material). Minimum co-efficient of permeability – 6.0x10-2 m/s [Typical assumed porosity – 30%]
- Capping layer, if required (coarse graded granular material); used where a bearing capacity, greater than can be offered by the unmodified founding native soils (subgrade), is required

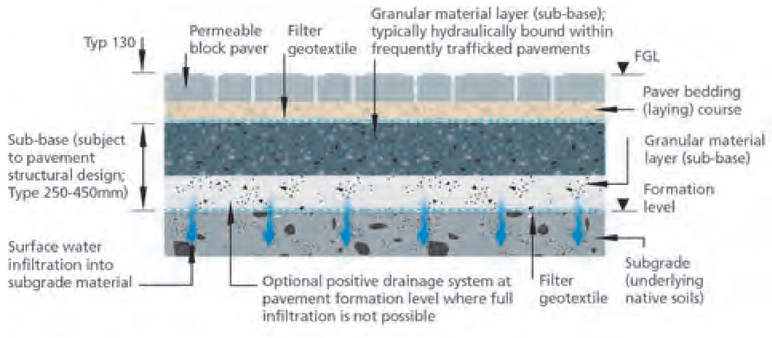
Improvement of the subgrade bearing capacity may also be undertaken, however, it should be noted that this would tend to be used only where infiltration into the native soils is not assumed to occur.

Further use of geosynthetics within the pavement construction, may also be considered to provide enhanced:

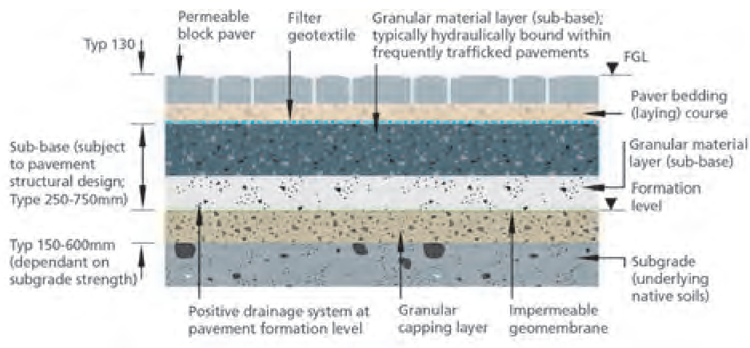
- Separation and water treatment – Geotextiles
- Reinforcement; effectively increasing the stiffness of a material layer – Geogrids
- Drainage functions – Geocomposites

Pavement construction therefore varies, depending on the pavement surfacing chosen, pavement location, site conditions and the proposed development's drainage scheme.

A permeable pavement system designed to allow infiltration into the underlying soils can typically have a minimum construction depth of between 380 and 580mm (assuming a saturated subgrade CBR ≥ 5%), depending on the category of vehicle trafficking that is expected. These depths may need to be increased where the supporting subgrade material is weaker, or additional water storage capacity is required within the pavement structure.



Type A permeable pavement infiltration



Type B permeable pavement attenuation

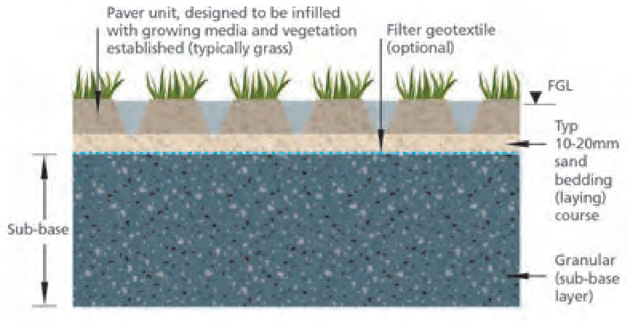
Typical alternative pavement surfaces

It should be noted that combinations of pavement types may be used i.e. concrete base layer beneath a porous asphalt surface in heavily trafficked areas.

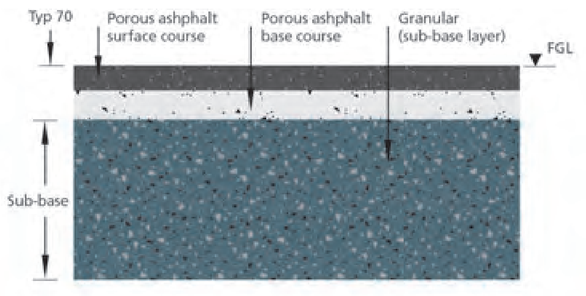
Where the surface gradient of a proposed pavement exceeds 3%, additional design measures would typically be required to minimise the loss of attenuation storage capacity within the system. This could include the subdivision of the pavement area into terraces, the creation of benching within the subgrade material, or check dams across the pavement sub-base to temporarily impound water within a series of discreet bays.

(Control of water on sloping sites – Fig 20.21 SuDS Manual (C753) guidance).

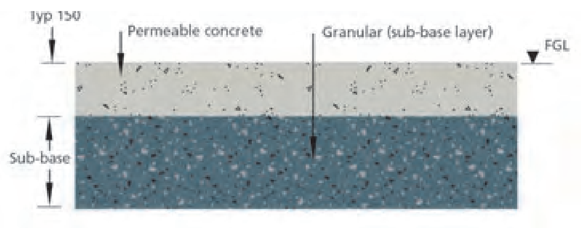
The pavement design should also consider the potential need for service corridors within the pavement structure that could effectively restrict the sub-base material available to allow lateral water flow through the system.



a) grass paver



b) flexible porous asphalt pavement



c) porous concrete pavement

Total (Type A) and (Type B) infiltration systems

Where the permeable pavement is designed to allow infiltration, a detailed geotechnical assessment of the subgrade material is required to complete both the structural and hydraulic designs.

Structural

The bearing capacity of the subgrade material being sufficient to support the proposed pavement structure and expected vehicle loading. In addition to the composition of the subgrade material being such that it will not be significantly weakened with the introduction of surface water.

Hydraulic

Whether the percolation rate of the underlying formation soils (subgrade) is sufficient to infiltrate the surface water that either falls onto the pavement, or is introduced into the pavement sub-base, from adjacent impermeable areas (i.e. building roof).

The pavement system type being considered feasible, where soil permeability co-efficient is:

> 1×10^{-6} m/s Type A pavements (total infiltration)

> 1×10^{-8} m/s Type B pavements (partial infiltration)

The incorporation of geotextiles within the pavement structure are typically used to act as a filter or separator between the distinct pavement structural layers, thus preventing the loss of the fine particles within a supporting layer into coarser graded underlying layers (i.e. block paver bedding coarse). Or the contamination of granular structural layers with fine material, leading to a loss of pavement strength (e.g. pumping action at the sub-base/subgrade interface, causing the migration of material between the two layers.

Partial infiltration systems typically have a positive drainage system installed at the pavement formation layer, enabling efficient collection and transportation of surface water to a specific point within the system, prior to allowing it to be discharged from the system into a downstream drainage system.

No (Type C) infiltration systems

Where the initial site assessment has identified that infiltration of surface water into the native soils is not feasible, typically when the soil permeability co-efficient is < 1x10-8 m/s, a non-infiltrating permeable pavement may still be used.

No infiltration systems typically require the entire below ground element of the system to be lined with an impermeable geomembrane.

As with a partial infiltration system, positive drainage systems are typically installed across the system footprint at the formation layer, to enable the efficient collection and transportation of water to a point within the system prior to it being discharged from the system into a downstream drainage system.

Where the pavement design requires a minimum depth of sub-base material to accommodate horizontal water flows through the system (i.e. partial or no infiltration systems), a detailed hydraulic analysis is required to ensure sufficient hydraulic capacity is available, to prevent increasing the risk of surface flooding during excessive rainfall.

3.6.6 Hydraulic benefits

A benefit of a permeable pavement system is that they do not require additional space, above that typically required by the development, to function. Where infiltration is feasible, permeable pavements are also able to manage the surface water at source, as water entering the pavement surface effectively flows vertically through the system before infiltrating into the underlying soils. They are able to provide the following hydraulic benefits:

Interception

Reducing the volume of surface water that may need to be discharged from the development. Research demonstrating that rainfall up to 5mm does not typically cause a discharge from permeable pavements, due to:

- Attenuation within the permeable material forming the pavement
- Surface evaporation

Infiltration

Reducing the volume of surface water that may need to be discharged from the development, via infiltration into the underlying soils, where feasible.

- Provides surface water attenuation storage capacity within the sub-base layer
- Reduces the total attenuation storage requirements of a development, as flow rates through permeable pavements tend to be significantly slower than other drainage systems; due to flows having to pass through the interconnected pores between the solid particles forming the pavement layers

Permeable pavements are able to accommodate surface water run-off from adjacent impermeable areas, either by surface flows crossing a permeable pavement surface, or via dedicated inlets within the pavement sub-base. As a rule of thumb, an impermeable to permeable pavement area ratio of 2:1, can typically be accommodated within a permeable pavement without the need for excessive increases in sub-base depth.

It should be noted that point inlets would typically require components to ensure the free dispersion of water into the sub-base storage layer; these can include perforated pipes or geocellular units.

(Pre-treatment and inlets – Section 20-10-1 SuDS Manual (C753) guidance)

3.6.7 Water treatment

A significant reduction in the potential pollution impact of surface water run-off can be obtained through the attenuation of run-off generated by high frequency rainfall events, typically approximated by a 5mm rainfall depth. Permeable pavements can offer opportunities to provide interception, through:

- Infiltration into the underlying soils, where technically feasible
- Attenuation within the pavement layers
- Evaporation

Due to the managed water flows having to pass through interconnected pores within the pavement structure, this facilitates the following treatment mechanisms to remove:

- Sediments, via filtration through the surface layers
- Nutrient and dissolved metals through biodegradation; the wet dry cycle typical within a pavement structure encourages bacteria colonisation
- Chemical compounds, through sorption to the granular particles that form the pavement structure

The inclusion of geotextiles within the pavement structure can also enhance the above mechanisms, while also minimising possible future maintenance activities and costs.

Where a point inflow is connected directly into the sub-base, the treatment of the surface water could be reduced, due to the water flow not being effectively filtered through the surface layers. Fine silt particles and other pollutants would still be removed through filtration, sedimentation and sorption within the granular sub-base material. However, this could then cause maintenance at the inlet location if the surrounding granular material becomes prematurely clogged. Therefore where these below ground point inflow connections are proposed, careful consideration should be given to the other SuDS components used within the upstream elements of the proposed drainage system design, to limit siltation risk and the associated reduction in hydraulic capacity.

It should be noted, when considering surface water run-off from extreme events, that run-off typically has a limited pollution impact due to the higher levels of dilution. Consideration should be given to exceedance flow routes across the pavement, or the possible temporary impounded water depth above the pavement surface considered at design stage (i.e. expected water depth and velocity does not pose a significant risk to users).

Permeable Paving, Walthamstow Stadium Development

3.7 Bioretention Systems

Bioretention systems are generally located within a shallow surface depression, at or below the level of the adjacent surfaces being drained.

They are designed to treat surface water run-off, which is distributed across the whole system surface, as it vertically flows through the system structure. Landscaping elements are used around the system perimeter to ensure an evenly distributed, low velocity, water flow into the system that also allows the temporary ponding of water above the filter media. Forebay areas may also be employed within larger bioretention systems, mainly to manage silt from high risk areas, that may otherwise cause premature clogging of the system surface.

Typically constructed using engineered soils, bioretention systems are able to employ a wide variety of planting (including trees and shrubs) to create vegetation cover across the system.

Bioretention systems offer an effective means of providing:

- Interception
- Volume and flow rate control
- Pollution treatment
- Cooling effects around the system; via evapotranspiration

Water treatment performance is influenced by the specification of the soils used to constitute the bioretention system, which act as filter media. In addition, anaerobic zones can be created within the system that further encourages the biodegradation of nutrients.

Where technically feasible, surface water draining through a bioretention system would normally be infiltrated into the soils underlying the system. Alternatively, an underdrain system is used to collect the surface water, prior to it being discharged into the downstream drainage system; which, due to the level of water treatment these systems are able to offer, may also include rainwater harvesting systems.

Bioretention systems offer a significant degree of flexibility with their sizing and specification, enabling them to be used within most types of development and soil types, particularly when receiving surface water run-off from sections of road surfaces. This often makes them a cost-effective solution for managing surface water pollution – in particular, where retrofitting SuDS.

(SuDS Manual (C753) guidance – Chapter 18)

Indicative Treatment Efficiency

Pollutant	Reduction: Inlet to Outlet
Dissolved Copper	≤ 60 %
Dissolved metals (e.g. zinc, lead, cadmium)	> 90 %
Suspended Solids	> 90 %
Phosphorous	> 80 %
Nitrogen	50 %

CIRIA C753; Table 18.1

Multifunctional benefits of bioretention systems

MAKING SPACE FOR WATER
Enhanced storage capacity by integrating geocellular or pipe solutions.

SURFACE WATER MANAGEMENT
Site level flow control.

WATER QUALITY
Offers source control treatment of silt via soil matrix and inclusion of treatment geotextiles.

PLACEMAKING
Creating attractive green spaces in urban areas that wouldn't usually be available.

EVAPORATIVE COOLING
The inclusion of rain gardens within developments can provide cooling via return of moisture to the air through evaporation/evapotranspiration from vegetation. Can reduce local temperatures. Can also reflect sunlight.

AMENITY
Enables easy integration into various designs, provides aesthetics, increase in vegetation, adds water treatment.

HEALTH & WELLBEING
Rain gardens that are accessible or overlooked can increase mental wellbeing.

BIODIVERSITY
Quality habitat for wildlife and plants, flexible in that this application can be added to both new and existing urban areas.

ASSET CREATION
Addition of gardens/green spaces can increase the aesthetic look of an area adding value to the property.

Increasing storage in bioretention systems – hydraulic benefits

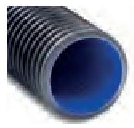
A Ridgidrain drainage system installed within a drainage layer below the bioretention system can allow simple integration into the drainage system. Inclusion of a perforated pipe within the granular drainage material to act as an underdrain can assist in the draining of bioretention systems.

Attenuation storage capacity can be increased within the system by providing a thicker drainage layer, or by introducing proprietry surface water storage systems within the layer, as a replacement to the granular material.

Polypipe is able to offer a number of product ranges that can be used for this application.

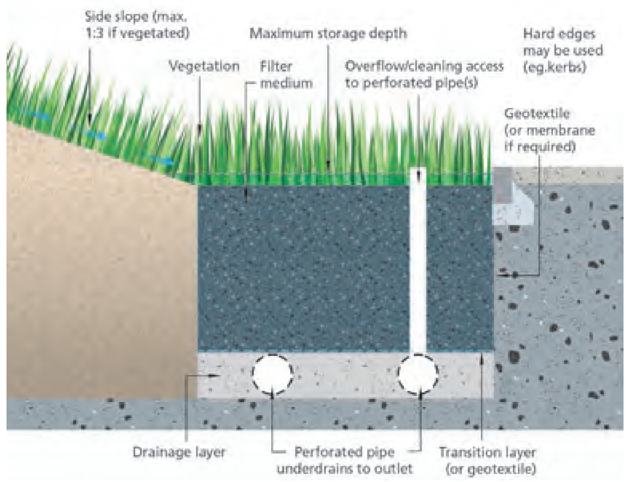
Landcoil

PVCu single walled flexible pipe land drainage system. Available in diameters from 60-200mm.



Ridgidrain

Thermoplastic structured walled surface water drainage system. Available as carrier pipe, half perforated and fully perforated and in diameters from 100-900mm, 6m in length, lighter in weight.



Components of a bioretention system (SuDS Manual (C753) guidance – Section 18.4; hydraulic design)

Increasing storage with geocellular components – hydraulic benefits

Consideration may also be given to increasing the potential attenuation storage provided within the granular drainage material achieved through the introduction of geocellular units from our Polystorm or Permavoid product ranges.

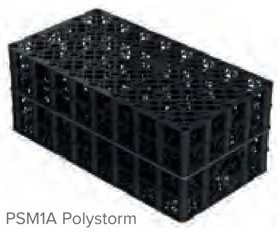
Polystorm geocellular unit

High porosity modular unit, providing significantly greater storage capacity compared with granular material requirements.

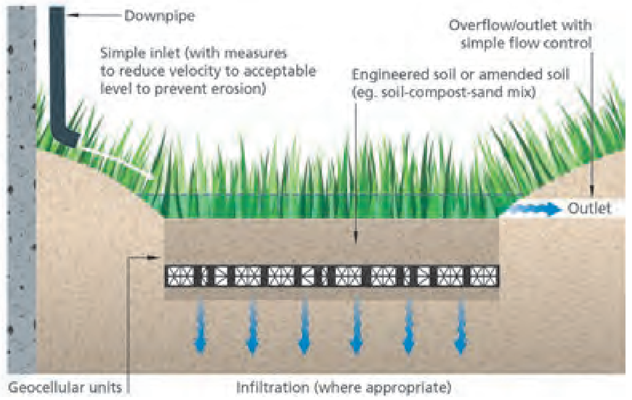
Permavoid

High porosity modular geocellular unit system.

The geocellular units can also behave as a conduit, provided a continuous installation is maintained, with flows typically driven by hydraulic lead.



PSM1A Polystorm Modular Cell



Section through a simple rain garden with outlet pipe (SuDS Manual (C753) guidance - Section 18.1.1)

Polypipe Geocellular Products

Code	Description	Length (mm)	Width (mm)	Depth (mm)	Storage per unit (m3)
PSM1A	Polystorm R	1000	500	400	0.19
PSM3	Polystorm Xtra	1000	500	210	0.099
PVPP85	85mm Permavoid Unit	708	354	85	0.020
PVPP150	150mm Permavoid Unit	708	354	150	0.036

Improved maintenance and inspection

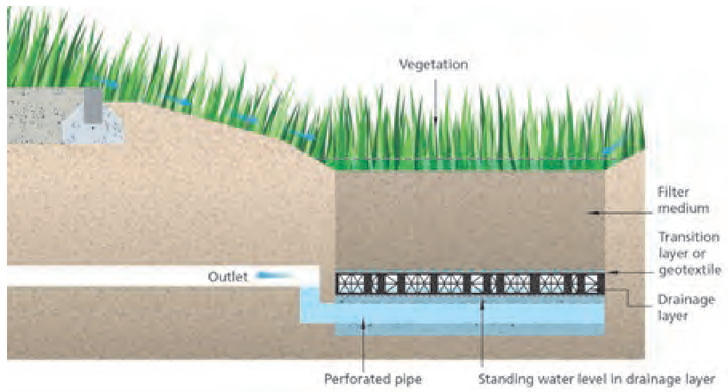
Installation of Polypipe's range of associated pre-fabricated chambers facilitate the inspection and maintenance of a drainage system. Polypipe chambers may also be used to incorporate a range of pre-fitted flow control devices, allowing simple introduction into the drainage system.

RIDGISTORMSeparate Catchpit

RIDGISTORMCheck Vortex Flow Control

Creation of anaerobic zones

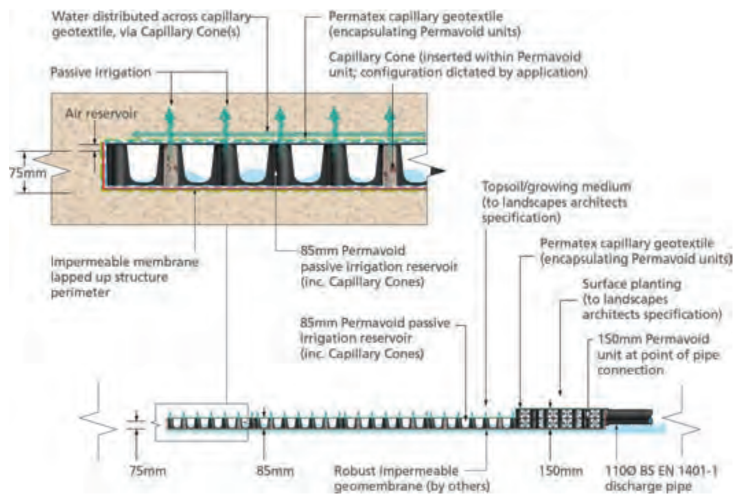
Permavoid and Polystorm units may also be used to facilitate the creation of anaerobic zones within bioretention systems, with the judicious use of geomembranes and flow control devices, prior to the surface water discharge from the system.



Anaerobic bioretention system (SuDS Manual (C753) guidance – Section 18.1.5)

Passive irrigation

Use of a Permavoid passive irrigation system beneath a bioretention system area, is able to serve the dual purpose of ensuring the system is positively drained, with a high strength load bearing system, while maintaining the soil moisture content via a reservoir of stored water. Irrigation is achieved through the use of an inert porous medium that draws water retained within the Permavoid unit and in conjunction with a hydrophilic geotextile, allowing the wicked stormwater to be distributed across a large surface area. The result is a zero energy irrigation system.



For more information please refer to: The SuDS Manual (C753), Section 18: Bioretention Systems.

Bioretention Systems Product Guide		
Product	**Description**	**Code**
Polystorm	May be used to disperse water from point inlets within the pavement sub-base.	PSM1A
Permavoid	Sub-base replacement: providing significantly higher storage capacity, compared with an equivalent depth of granular sub-base material.	PVPP85 PVPP150
Permavoid Rainwater Diffuser Unit	Used to disperse surface water from point inlets, where discharged within the sub-base.	PV09011
Permavoid Biomat	Incorporated within a Permavoid structure, typically restricted to the location of point inlets, to provide additional hydrocarbon treatment.	PV150BM
Permafoam	An open celled absorbent phenolic foam incorporated into Permavoid geocellular units for 'on demand' irrigation or check dams.	PVPP85PF PVPP150PF
Permachannel	Collection of surface water run-off from an impermeable pavement surface, includes elements that provide a high strength of initial water treatment.	PV03001
Permatreat	Available in two grating options, Permatreat is a versatile, linear treatment system that can provide source control and pollution treatment in a wide variety of locations and applications.	-
Permafilter	Proprietary geotextile designed to offer enhanced hydrocarbon pollution treatment, typically installed beneath the surface layer(s).	PV23002
Geomembrane	May be used to form check dams within the permeable pavement construction, limiting loss of attenuation storage, within developments containing steep gradients.	-
Permatex 300 Geotextile	A heavy duty, non-woven, needle punched, polypropylene geotextile designed to protect and separate Permavoid geocellular layers.	PV23006
Capillary Geotextile	A heavy-duty, non-woven, needle-punched geotextile made from a blend of modified polyester fibres. It is specially formulated to absorb water used to irrigate mineral substrates when used in conjunction with Permavoid units.	PV23008

3.7.1 Conventional SuDS – typical construction

The system inlet requires careful detailing to ensure a low velocity, evenly distributed flow across the system surface. Forebays may be used within larger bioretention systems to further control water flows, provide a basic flow of initial water treatment and facilitate maintenance.

Water run-off from the adjacent surfaces being drained would typically be channelled into the bioretention system, with the water potentially ponding on the surface before flowing through the vegetation and engineered soils.
(SuDS Manual (C753) guidance – Section 18.1)

Bioretention systems may be installed on most types of development and have been widely used to manage pollution within road surface water run-off, with individual bioretention systems typically used to drain small catchment areas, located close to the run-off source. In order to maintain the efficiency of the system and allow access for maintenance activities, bioretention systems would typically be designed using the following dimensional rules:

- Recommended maximum 0.8 ha surface area draining to a system
- System surface area at least 2-4% of the drained surface area
- Typical system width between 0.6-20.0m (subject to access)
- Maximum system length of 40.0m (subject to access)
- Maximum total system filter area of 800m^2

Bioretention systems may also be sub-divided, or tiered, to give further options when managing larger systems. The bioretention systems are typically constructed with a number of distinct elements, or zones, which are summarised below:

Inlet

Designed to evenly distribute water flow across the system surface, minimising the risk of surface erosion, or localised overloading of the pollution treatment capacity of sections of the engineered soils (restricting flow velocities < 0.5m/s; <1.5m/s during extreme rainfall). Typically, a minimum 500mm wide, to reduce the risk of blockages.

Forebay (optional)

Where the management of siltation is a particular concern, an initial forebay can be incorporated into the system design to trap sediment. The size of the forebay is dictated by the size of the bioretention system, expected sediment load within the system inflow and desired minimum maintenance frequency.

Forebays may be submerged or include dense vegetation to encourage sedimentation.

Temporary Surface Detention

Landscaping elements are used around the system perimeter (i.e. pavement curb) and are typically used to allow the temporary ponding of water, the design depth dictated by the water treatment volume that the system needs to be effective (typically maximum 150 – 300mm depth).

Surface Vegetation

Choice of vegetation can have a significant effect on the efficiency of the bioretention system, due to:

- the plant species efficiency in up-taking pollutants
- enabling chemical process within the soil
- the engineered soil permeability being maintained by the rhizome root systems
- preventing erosion of surface material

The planting tolerance to shading, height and maintenance requirements should be considered to ensure adequate long term performance of the system.

Filter Medium

Typically a 400-1000mm deep zone of sand-based engineered soil, containing organic matter. Designed to support the surface vegetation and perform as an effective pollution filter. Appropriate material specification is critical to ensure adequate hydraulic conductivity and limit the risk of over-compaction or structural collapse.

Transition Layer

Typically a minimum 100mm thick granular filter layer, designed to prevent fines being washed from the overlying filter medium; alternatively, an appropriately specified geotextile filter layer could be used.

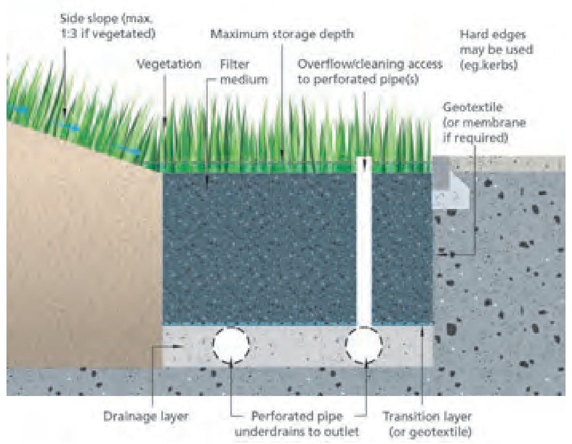
Drainage Layer

A granular filter material which collects the water flowing from the transition layer, via the filter medium, making it more readily available for the collecting conduit to discharge from the system. The depth of this layer is typically dictated by the size of the conduit and its minimum cover depth requirements.

Flow controls may be introduced at the system outlet, allowing use of the drainage layer to provide attenuation storage.

Overflow

Element(s) designed to direct flows downstream, once the hydraulic capacity of the system has been exceeded during extreme rainfall events.



Components of a bioretention system (SuDS Manual (C753) guidance – Section 18.4; hydraulic design)

3.7.2 Raised planter

Bioretention systems may be installed within raised planters, utilising a similar construction.

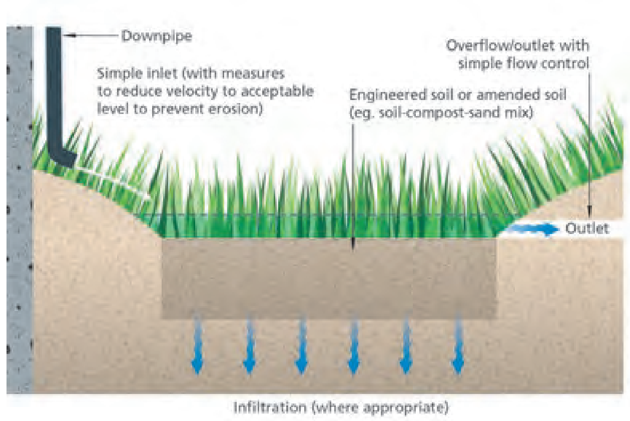
Typically used where infiltration into the underlying native soils is not technically feasible or the below ground drainage system, into which the outlet will discharge, is installed at a relatively shallow depth.

(SuDS Manual (C753) guidance – Section 18.1.2)

3.7.3 Rain garden

Where the surface area being drained to the bioretention system is limited, typically when installed to receive surface water from a single residential property, the system design may be significantly simplified.

The simpler system installations, typically known as rain gardens, combine the filter and drainage layers using a 200-500mm thick layer of improved site won (native) soil, or a sand-based engineered soil, to support the surface vegetation and perform as a pollution filter. Additional attenuation storage may be provided within this layer, in a similar manner as the drainage layer within bioretention systems.

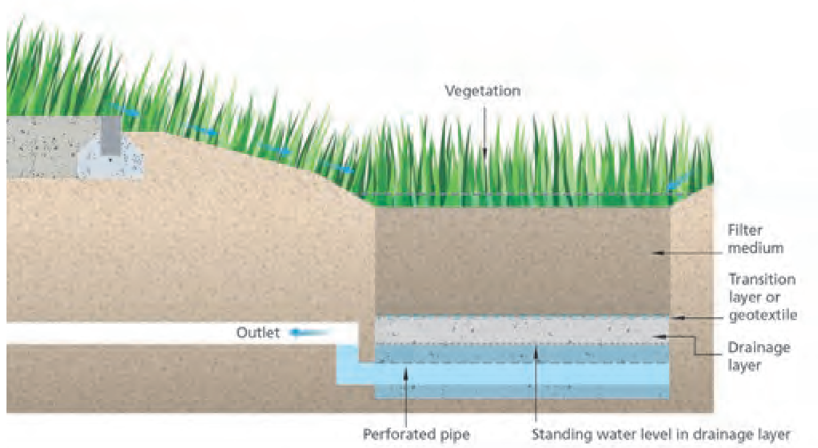


Section through a simple rain garden with outlet pipe (SuDS Manual (C753) guidance – Section 18.1.1)

3.7.4 Anaerobic bioretention system

The outlet from an anaerobic system is designed to create a permanently saturated (anaerobic) zone within the drainage layer.

This stored water may then be accessed by the surface planting during dry periods; however, the system requires careful design to ensure that the root zone soil does not become waterlogged.



Anaerobic bioretention system (SuDS Manual (C753) guidance – Section 18.1.5)

3.7.5 Hydraulic benefits

Provided the bioretention system is designed with sufficient surface storage to retain the design surface water run-off treatment volume, prior to its filtration through the system (typically associated with 150-300mm water depth), the units are able to provide the following hydraulic benefits:

- Interception and infiltration; reducing the volume of surface water that may need to be discharged from the development, through:
  - Infiltration into the underlying soils, when feasible (refer to 3.9)
  - Attenuation within the filter media matrix, and
  - Via evapotranspiration
- Provides attenuation storage capacity within the filter media and drainage layer
- Reduces the total attenuation storage requirements of a development, as flow rates through bioretention systems are significantly reduced; due to the surface water having to percolate vertically through the system

It should be noted that the bioretention systems are designed for intermittent flows, which ensures that the surface soils do not become saturated for extensive periods of time. Wet conditions would encourage the growth of moss etc. on the soil surface, which would significantly reduce the surface soil permeability, reducing the system's hydraulic capacity.

Maximum water treatment efficiency is typically achieved when vertical water flow through the system occurs over 24-48 hours.

Bioretention systems may be used to provide specific attenuation storage within the granular drainage layer, prior to its discharge from the system. Where the system discharges to a downstream drainage system, a flow control may be introduced at the system outlet, with the drainage layer then used to provide attenuation storage. Attenuation storage capacity can be increased within the system by providing a thicker drainage layer, or by introducing proprietary surface water storage systems within the layer, as a replacement to the granular material.

Hydraulic benefits - Raised planters

Raised planters offer additional flexibility in the provision of attenuation storage, when designing a developments drainage system. The attenuation storage effectively being created above ground, which, in conjunction with the dimensional flexibility of the system, provides an effective contribution when retrofitting SuDS within an existing development.

3.7.6 Water Treatment

Bioretention systems offer effective water pollution management, with the system's dimensional flexibility allowing them to be used on a wide range of development types – especially beneficial when considering the retrofitting of SuDS.

The design of bioretention systems are based on vertical water flows through the system. With an appropriately sized system, they are able to retain the surface water run-off treatment volume at the system surface until it is subsequently able to percolate vertically through the system within a 24-48 hour period. As noted in Section 3-5-2, bioretention systems should be designed to prevent the upper sections of the system being saturated for significant periods of time; to minimise the risk of future maintenance problems. However, anaerobic zones can be established at the base of the system to enhance the treatment of nutrients.

A wide range of planting types and densities can also be accommodated within the system; enabling plant species that are efficient in pollutant uptake.

Significant reductions in the potential pollution impact of surface water run-off can be obtained through the attenuation of run-off generated by high frequency rainfall events, typically approximated by a 5mm rainfall depth. Bioretention systems can offer opportunities to provide interception, through:

- Attenuation within the soil matrix that supports the surface planting/vegetation; in addition to within the underlying filter media
- Evapotranspiration

Further water treatment is achieved as surface water percolates through the filter and drainage media. Optimum hydraulic conductivity for this material is considered where flow rates between 100-300mm/h is maintained. This enables the following treatment mechanisms:

- Sediment removal, via filtration through the surface vegetation and filter media
- Nutrient and dissolved metal removal, through biodegradation and plant uptake
- Chemical compounds, by photolysis and volatilisation
- Sorption with the filter media particles

When considering surface water run-off from extreme events (which typically have a limited pollution impact due to the higher levels of dilution) careful consideration should be given to the design of the system overflow or exceedance flow routes. This will help to minimise the risk of surface ponding exceeding the system design, which could damage the vegetation and tree(s) and increase the risk of the soil permeability being reduced through biological clogging.

3.8 Attenuation Storage Tank

Any structure that creates a below ground void that may be used to temporarily provide surface water storage prior to infiltration, it being reused or discharged in a controlled manner are generically termed as attenuation storage tanks.

Geocellular systems

These are high porosity modular thermoplastic units, requiring encapsulation with geosynthetic(s). They can be formed to create attenuation tanks of infinite different sizes and shapes. This is generally the product of choice for private surface water drainage applications.

Pipe and engineered stormwater systems

Where it is proposed that the ownership of the attenuation storage tank itself, or the asset below which the attenuation tank will be installed (i.e. road), will be adopted by another organisation such as a sewerage undertaker or local highways authority respectively. The preferred solution is a tank sewer or multi-legged engineered stormwater solution. These organisations may require the attenuation storage tank proposals to undergo a technical approval process prior to ownership being transferred. All interested parties should therefore be consulted at the earliest possible stage of a proposed developments design.

(SuDS Manual (C753) guidance – Chapter 21)

Consideration should be given to how these storage systems are integrated within a development's overall drainage design, to ensure an appropriate level of water pre-treatment is achieved prior to systems becoming operational. Where the available space for surface drainage systems is restricted within a development, attenuation storage tanks can allow other SuDS elements within a drainage system to be optimised to provide the maximum level of water treatment, by preventing them from being overwhelmed during excessive rainfall.

Integrating attenuation storage tanks within the drainage design may therefore allow the effectiveness of SuDS elements within existing proposals to be enhanced, or facilitate the addition of a SuDS Treatment Train.

The main benefits offered by attenuation storage tank systems are that they are able to provide:

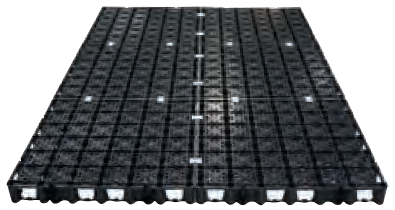
- Significantly higher storage volumes compared to granular filled structures
- Have the ability to be installed beneath areas with a primary purpose other than drainage. These can include amenity (i.e. public open spaces), trafficked (i.e. roads or parking areas) or heavily loaded areas (i.e. ports); subject to suitable structural assessments being undertaken

In the event of a spillage, the maximum reduction of spillage risk considered achievable:

Optimum Risk Reduction Factor RF 1.0 (100%) **

** Possible provided appropriate control(s) are included at the system outlet and that the system provides the option to remove the spillage (i.e. penstock valve within an access chamber).

Polystorm



Permavoid² 85

Ridgistorm-XL Jointing Frame

Multifunctional benefits of attenuation storage tanks

Making space for water
Enhanced storage capacity by integrating geocellular or pipe solutions.

Surface water management
Site level flow control and conveyance.

Water quality
Water treatment offered via lateral flow of water through the vegetation in the swale. Enhanced with the inclusion of treatment geotextiles.

3.8.1 Polypipe GI

Polypipe is able to offer multiple systems that may be used to provide attenuation storage within a development. This enables Polypipe to supply fully integrated below ground drainage elements, which may be composed of a number of differing systems, each chosen to suit the proposed location within the development.

Permavoid and Polystorm modular geocellular units have uniform shapes, allowing the structural cross-sectional area within an excavation to be maximised. This minimises the volume of granular material required to form nominal bedding and protective layers; assuming adequate bearing capacity of the underlying native soils. Compared with pipe, arch and tank systems, geocellular units are therefore typically able to provide more efficient attenuation storage capacity on a volume (m^3) basis.

Both Polypipe geocellular product ranges allow three-dimensional flow through the individual modular units and assembled structure. Thereby maximising the utilisation of the attenuation storage capacity of the structure – while minimising the risk of any obstruction or blockage within the geocellular structure, that could cause a detrimental flow restriction within the system or hydraulic failure.

Polypipe's geocellular offering includes a number of proprietary elements that allow the ability to retain surface water within an attenuation system. It can then be used as a valuable water resource, whether as part of a rainwater harvesting system (i.e. non-potable water applications, such as toilet flushing) or as part of a passive irrigation system when installed beneath areas of surface planting.

Ridgistorm-XL thermoplastic structured walled pipe system attenuation storage tanks offer flexibility, both at the design and construction phases, with the system enabling the simple inclusion of a range of:

- Access chambers, whether inline of offset
- Access and inspection turrets within the body of attenuation storage tank units
- Inlet and outlet pipe connections
- Flow control devices within the attenuation system

A fully integrated attenuation storage system enables the overall footprint of the storage structure to be minimised, while maintaining the access which may be required to carry out maintenance activities.

Polypipe is able to offer a number of product ranges that can be used to create attenuation storage tanks within a development:

Permavoid

Modular thermoplastic injection moulded geocellular unit system, with a high porosity. The Permavoid system consists of relatively shallow units that utilise a patented jointing system, enabling the formation of a high compressive and tensile strength raft. The system offers a range of ancillary units that can be simply integrated to provide higher levels of water treatment or facilitate surface water reuse.

Polystorm

Modular thermoplastic injection moulded geocellular unit system, with a high porosity. The Polystorm system offers a range of units that may be simply integrated to offer a flexible system that can be value engineered to meet site specific conditions; including units designed to facilitate inspection and maintenance.

Ridgistorm-XL

Thermoplastic structured walled surface water drainage system that is currently available in diameters from 750-3000mm as standard. The Ridgistorm-XL flexible manufacturing process, allows Polypipe to offer pipes that are value engineered to suit site conditions which, in conjunction with a comprehensive range of fabricated fittings and chambers, offers a fully integrated system.

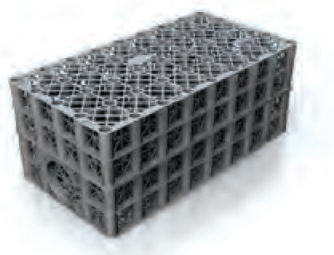
Ridgistorm Fabricated Chambers

Polypipe is able to utilise its range of large diameter pipes to pre-fabricate a comprehensive range of manhole, access and inspection chambers. Chamber units may be designed to incorporate a range of pipe connections and can be pre-fitted with a number of flow control and water treatment elements.

Polypipe Geocellular Products

Code	Description	Length (mm)	Width (mm)	Depth (mm)	Storage per m
PSM1A	400mm Polystorm Unit	1000	500	400	0.19
PSM2	400mm Polystorm Unit	1000	500	400	0.19
PSM3	200mm Polystorm Unit	1000	500	210	0.105
PSM4	400mm Polystorm Inspect Unit	1000	500	400	0.2
PSM5	Polystorm Deep	1000	500	400	0.19
PSMA	Polystorm Access Unit	-	-	-	-


Permavoid 85 geocellular unit

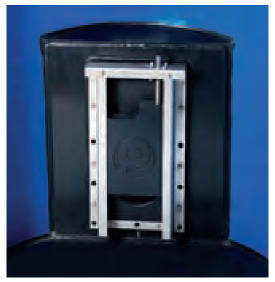

Polystorm geocellular unit


Ridgistorm-XL


RIDGISTORMSeparate Catchpit


RIDGISTORMCheck Vortex Flow Control


RIDGISTORMSeparate-X4


RIDGISTORMControl Chamber

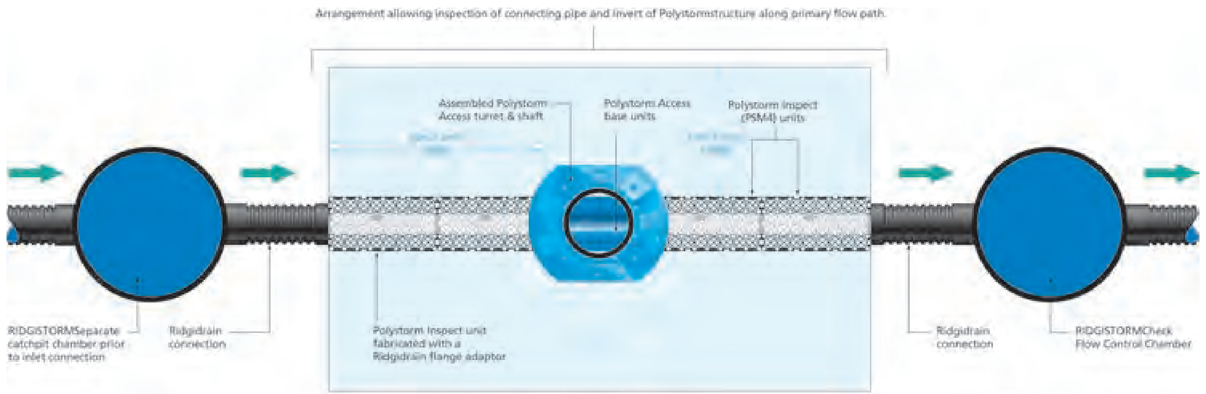
Polystorm

The diagrams below illustrate how a Polystorm on-line and off-line attenuation storage structure may be constructed respectively. This illustrates how different units within the Polystorm system may be integrated within the same installation, offering maximum flexibility to system designers to enable the generation of value engineered installations.

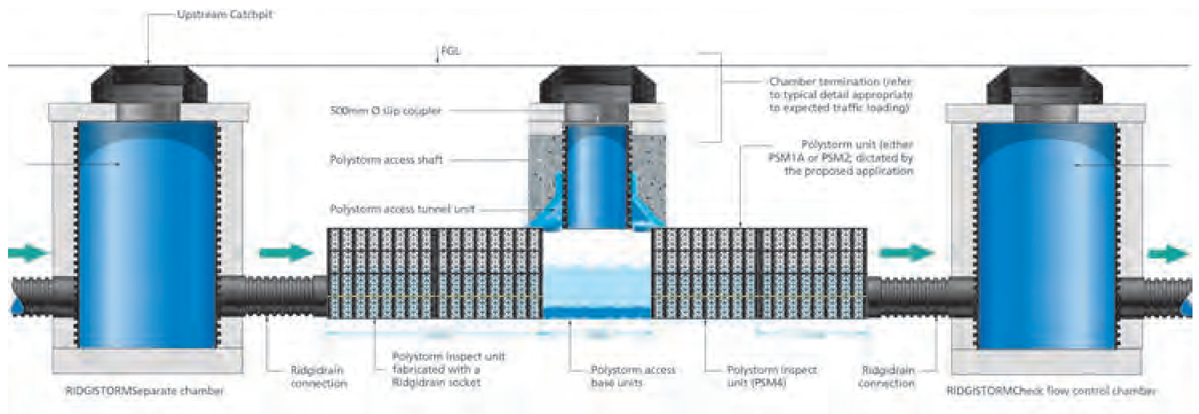
Polystorm Access and Inspect units may be installed within selected areas of the storage tank to enable effective monitoring of the performance of the system. Installation of an off-line storage tank will result in the storage structure only being utilised during extreme rainfall events, reducing the potential maintenance activities that may be required i.e. minimising siltation risk.

Polypipe Fabricated Chambers may be used in conjunction with the Polystorm system to provide basic water treatment (e.g. RIDGISTORMSeparate, RIDGISTORMCheck and RIDGISTORMControl).

Polystorm on-line solution

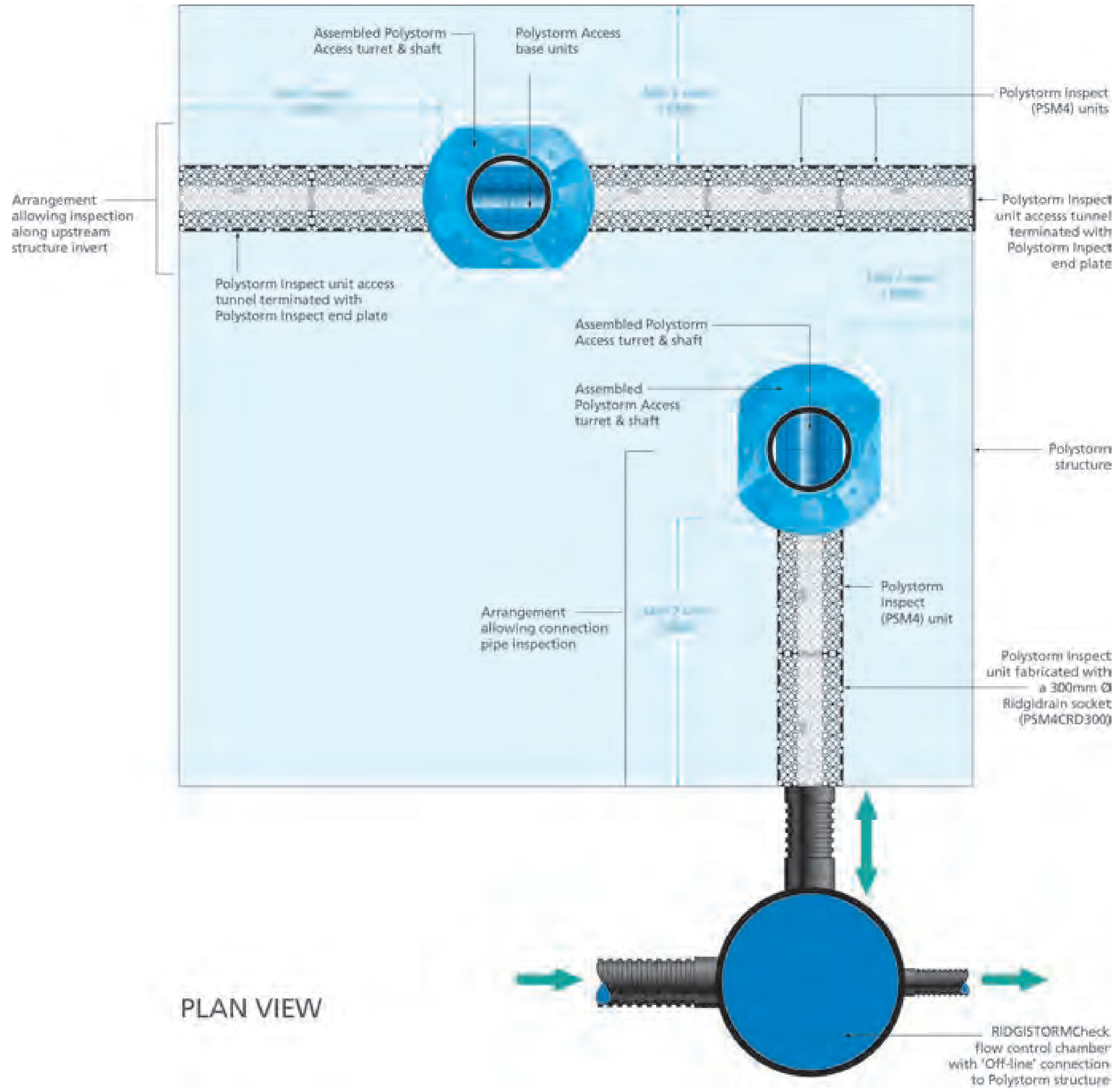


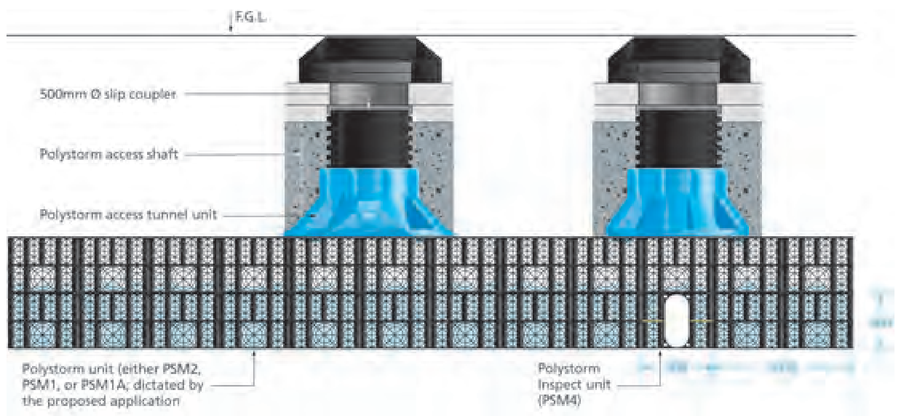
PLAN VIEW



SECTION 1-1

Polystorm off-line solution





Ridgistorm – engineered stormwater attenuation

Ridgistorm-XL

The Polypipe Ridgistorm-XL system can be engineered to suit any application by analysing the site conditions and installation parameters. Storage solutions, using an appropriate stiffness classification, can then be manufactured to suit the specific design requirements of the proposed installation. The flexible nature of the Ridgistorm-XL system minimises the effect of potential ground movements (i.e. differential settlement) and deformation, with a system lifetime expectancy in excess of 100 years. Pipes can potentially be supplied in lengths of up to 12.0m, reducing the number of joints required within the system.

A Ridgistorm-XL attenuation storage tank is typically formed from single or multiple pipe runs that are terminated and linked together, where applicable, with fabricated fittings. The units that comprise the storage tank may also include fabricated pipe connections, inspection turrets and access points; providing a fully integrated system. This enables the number of construction activities that are required on-site to be minimised, as the units are fabricated off-site, within Polypipe's dedicated fabrications department. An example of a multiple pipe run installation is given below.

The Ridgistorm-XL system can also be supplied with a number of jointing methods to suit the project conditions, ranging from:

Ring seal

EPDM ring seals are supplied as standard, with nitrile seals available on request. Currently available for pipe diameters up to 1800mm.

Electro-fusion welding

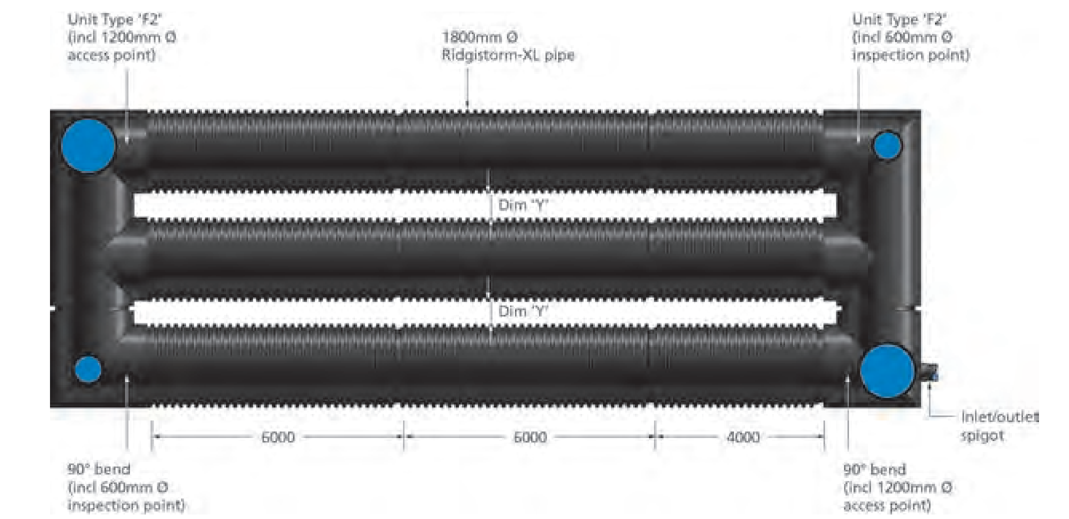
The integrated electro-fusion jointing elements create a homogeneous system.

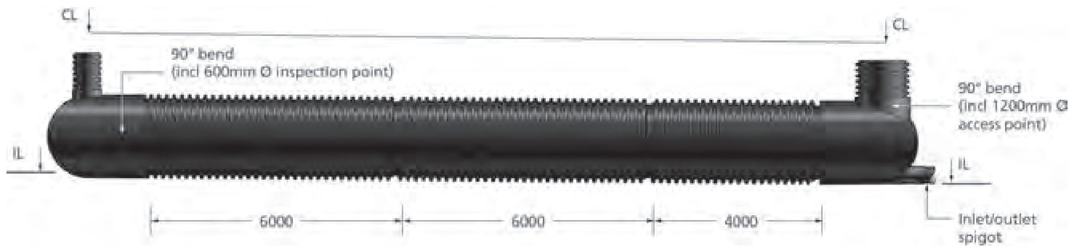
Internal Extrusion Welding

Joints are extrusion welded internally by the Site Services Team.

Further specialist jointing methods i.e. flange and mechanical pipe couplers are also available.

Polypipe is also able to offer a range of standalone pre-fabricated chambers, designed to facilitate the simple inclusion of a range of flow controls within a drainage system.





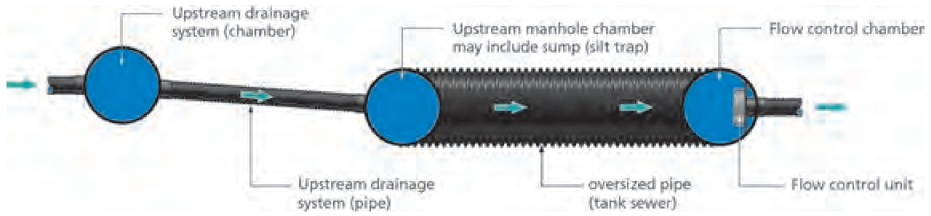
3.8.2 Conventional SuDS

Typical construction

Below ground attenuation storage is typically integrated within a drainage system in one of a number of basic ways, generically termed as:

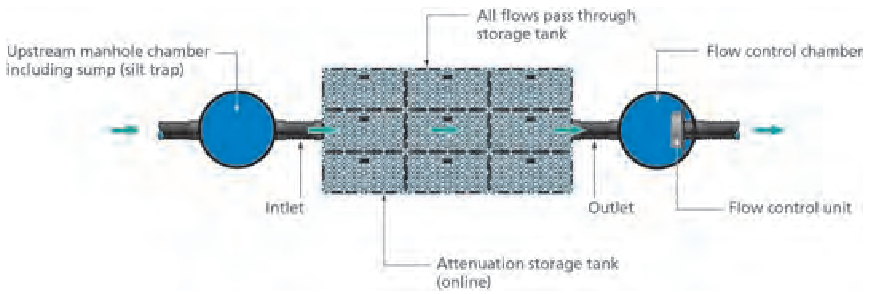
Tank sewer

Where a conduit pipe within a below ground pipe system is oversized to provide additional dedicated attenuation storage.



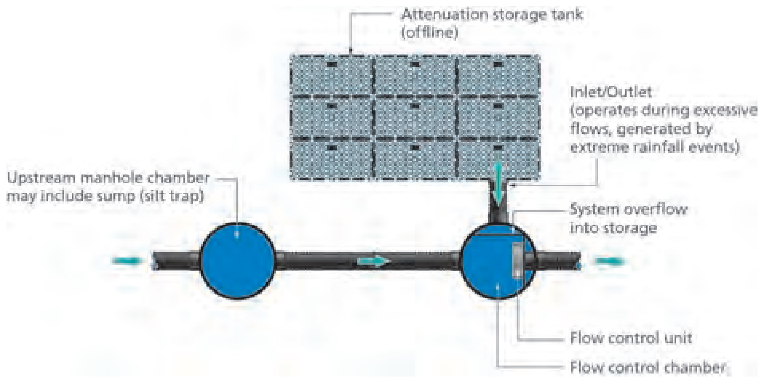
On-line storage tank

Where all of the flow that passes through the drainage system, flows through the attenuation storage tank.



Off-line storage tank

Where during normal operation of the drainage system, flow by-passes the attenuation storage, the storage tank only being utilised during conditions caused by excessive rainfall. This is typically managed with the integration of appropriately designed flow control(s) within the drainage system, diverting flows into the attenuation storage tank, then allowing a controlled release from the attenuation storage when conditions allow.



The attenuation storage tank itself is typically installed at a relatively shallow gradient (i.e. 1 in 400 to 500), in order to maximise the utilisation of storage within the system, while ensuring the system is not installed at a reverse gradient or ponding occurring along the system invert.

3.8.3 Geocellular systems

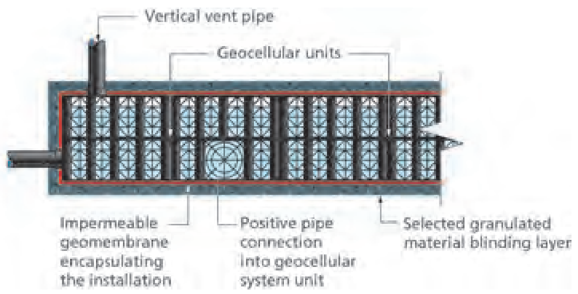
'Geocellular unit' is the generic name given to a range of proprietary plastic modular cell systems. Manufactured with a high porosity, the varied systems typically comprise a combination of standard units that may be combined to form larger below ground attenuation storage or infiltration structures. Within the market place a wide range of distinct systems have been developed, each unique to their manufacturer.

Wilson (2008) initially suggested a method of classifying the various proprietary systems into one of three categories. It should be noted that as a consequence of the varying proprietary geocellular unit composition, the method each proprietary geocellular system employs to utilise its storage capacity may vary between system types.

Polypipe advocates the use of:

Positive pipe connection

Where inlet/outlet pipes are connected directly onto a geocellular system unit, with flow directly into the geocellular structure.



Positive pipe connection

Alternative methods to achieve water flow into and out of the geocellular storage may be employed, in instances where site conditions specifically dictate their use. These methods may include:

Adjacent perforated distribution pipe

A perforated pipe is installed within a granular layer, which runs along an entire geocellular unit face.

Integrated perforated distribution pipe

Where a perforated distribution pipe is integrated within a geocellular block of granular material within the structure.

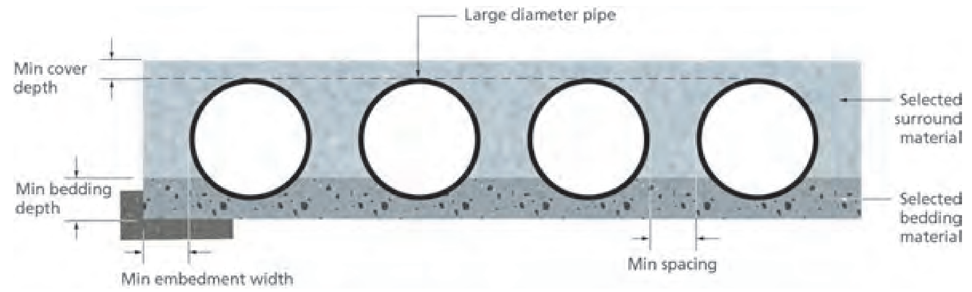
The geocellular units effectively act as a void-former and need to be encapsulated in a geosynthetic to prevent backfill material from falling into the units. It should be noted that where an adjacent perforated distribution pipe is used, the granular material would typically need to be encapsulated within a geotextile and this then included within the geomembrane encapsulation of the whole installation.

The geocellular storage structure is typically installed on a nominal bedding layer, to ensure a level formation and provide protection to the geosynthetic encapsulation. With a further protective layer of material installed around the remaining structure faces, primarily to protect the geosynthetic.

3.8.4 Large diameter pipe systems

Large diameter pipes are available from a number of product manufacturers, who use a variety of materials in their manufacture. However, the typical general arrangement of large diameter pipe attenuation storage tanks are broadly the same, irrespective of the material. With differences typically occurring in the recommended:

- Pipe bed and surround details
- Minimum pipe spacing, where multiple adjacent pipe runs are proposed
- Integration of system access and inspection chambers into the system
- Pipe run termination details



Typical cross section – large diameter pipe installation

(Oversize plastic pipes; Section 21.1.4 SuDS Manual (C753) guidance)

3.8.5 Hydraulic benefits

Attenuation storage is designed to provide the storage capacity required to limit the risk of unplanned surface flooding during excessive rainfall.

These systems may be used to accommodate flows over and above the optimum water treatment velocity (or volumes) of downstream SuDS elements generated during extreme rainfall events [typically in excess of the 1 in 1-year (100% probability) rainstorm]. Thereby limiting the potential of damage to any downstream surface drainage elements or re-entrainment of captured sediments; but also allowing the systems to be optimised for water treatment. This offers the drainage designer further options for the use of SuDS within the development, especially on space-constrained sites – with the attenuation storage tank being able to be situated beneath surface areas with another primary use (i.e. car parking or road).

3.8.6 Water treatment

Typically storage tanks themselves do not offer any significant form of water treatment, although they may incorporate basic silt traps or proprietary products that offer a defined level of treatment for specific pollutants.

Within a well-designed drainage system, the use of storage tanks can be utilised to control the water flow through downstream drainage elements, enabling these drainage systems within the development to be designed to optimise water treatment efficiently.

Permavoid and Permachannel – attenuation, Porth Station

3.9 Infiltration Systems

In simple terms, anything that allows water to pass through to the soil below is, essentially, a filtration system.

Designed to enable, or enhance, the infiltration of surface water run-off into the ground, a filtration system can be used in isolation but also as part of a 3D (multiple plane) infiltration system.

In the context of SuDS design, a hierarchical approach is taken to how surface water should be managed within a development, where infiltration systems are required to be considered in the first instance, prior to options that result in a discharge outside the development; whether this is to an adjacent river, watercourse or sewer.

Irrespective of whether it would be used to either support or preclude infiltration use within the proposed development, a detailed evaluation of your site will still need to be produced. Where ground conditions only allow limited infiltration, which prevents surface water being entirely managed within the development, infiltration may still offer an important contribution towards interception.

Infiltration of surface water can offer the following potential benefits:

- Reduces the total volume of run-off discharged outside a development; thereby reducing the total attenuation storage that may be required, in addition to delivering interception for the contributing surfaces drained to the system
- Replenishes local ground water, which may also help support local water course base flow
- Maintains site soil moisture levels, supporting vegetation and planting and, in turn, attracts biodiversity

Indicative Treatment Efficiency

The effectiveness of a surface water infiltration system to protect potential groundwater receptors is typically dependent on the depth and composition of unsaturated soils through which the surface water will infiltrate, along with the surface area over which infiltration occurs.

Multifunctional benefits of infiltration systems

MAKING SPACE FOR WATER
Extensive range of systems to suit site specific requirements.

AMENITY
Space saving, can be buried underneath locations which provide amenity.

SURFACE WATER MANAGEMENT
Source or site flow control.

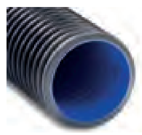
WATER QUALITY
Can offer multiple levels of treatment when combining the use of geotextiles, component chambers and aggregate.

3.9.1 Polypipe GI solutions

If site constraints limit the size or depth of landscaped depressions (i.e. swale), the addition or extension of below ground elements within the system may still enable surface systems to be used. This can offer the dual benefit of increasing the level of flood protection within the development, while facilitating the maximum treatment efficiency and biodiversity opportunities of surface SuDS.

Polypipe is able to offer a number of products that can significantly increase the storage capacity of below-ground elements (i.e. granular material alternative):

- Increase storage capacity within below ground system elements



Ridgidrain/Ridgistorm

Thermoplastic structured walled surface water pipe systems. Available as carrier, half perforated and fully perforated in diameters 100-3000mm, 6m lengths and lighter in weight.

Polystorm

The Polystorm cell, made of virgin material, is ideally suited for trafficked and loaded areas at greater depths.

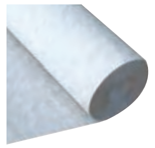
Permavoid

High load bearing and porosity modular units, providing significantly greater storage capacity compared with soil and aggregate media.

It should be noted that, where geocellular units are designed to act as a conduit within the infiltration system; due to the internal structure of these units, they may enable slower rates of flow through the structure compared with alternative conduits (i.e. pipes). A potential benefit of slowing the rate of flow through drainage systems is to offer opportunities to reduce the total storage capacity requirements within the drainage design.

If an infiltration system consists of multiple distinct strata, through which the surface water is designed to flow, there may be a requirement for the installation of filter layers at the interface of these strata. Polypipe is able to offer the following proprietary geotextile that can offer enhanced hydrocarbon treatment:

- Enhanced pollutant treatment (hydrocarbons)



Permafilter geotextile

Proprietary non-woven geotextile; designed to catch, filter and facilitate the breakdown of hydrocarbons.

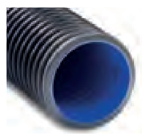
Where an infiltration system includes a large element of granular medium, inclusion of conduits within the infiltration structure can ensure that surface water is evenly distributed throughout the entire structure, maximising the system's ability to infiltrate surface water while minimising the risk of sections of the system being overloaded by pollutants.

Polypipe has a number of products that may be used to serve this basic distribution function within an infiltration system:

- Assisted distribution of surface water across an infiltration structure

Landcoil

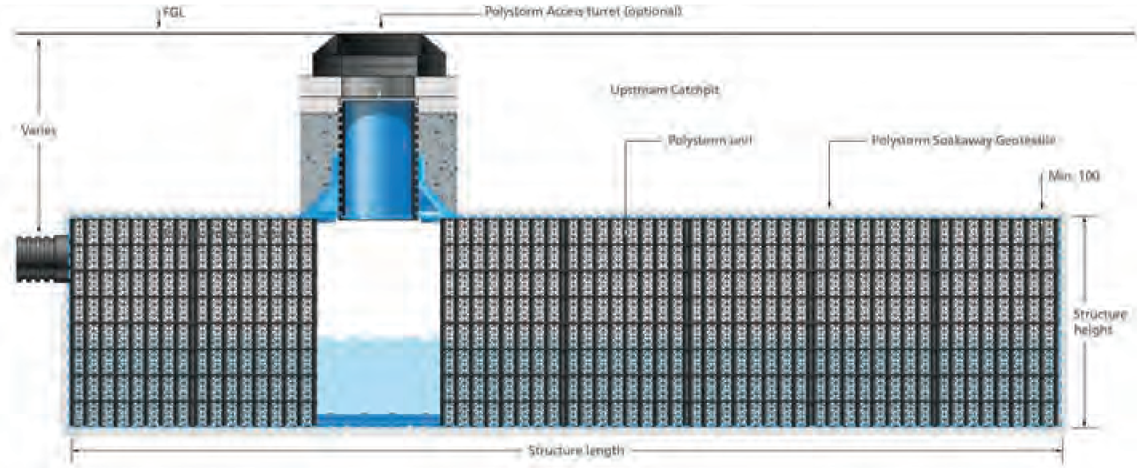
PVCu single-walled flexible pipe system manufactured to BS 4962. Available in diameters from 60-200mm.



Ridgidrain

Thermoplastic structured walled surface water pipe system. Available as carrier, half perforated and fully perforated in diameters 100-900mm.

3.9.2 Conventional SuDS – soakaways – infiltration: primary function

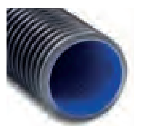


Ridgistorm pre-fabricated chamber (Section 2.6)
Off-site constructed pre-fabricated chambers with perforations are available in sizes of 450-3000mm with depths and inlets to suit the site requirements. The light in weight and easy to install units are installed within the soakaway excavation and surrounded with granular fill.

Polystorm geocellular unit (Section 2.5)
High porosity modular unit, providing significantly greater storage capacity compared with granular material (void ratio of 95%); in addition to reducing the granular fill surround requirements compared with an equivalent chamber soakaway.

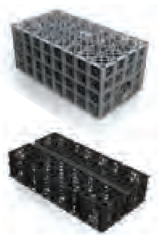
3.9.3 Infiltration trench – infiltration: primary function

Geocellular units or pipes can be used to form a conduit.

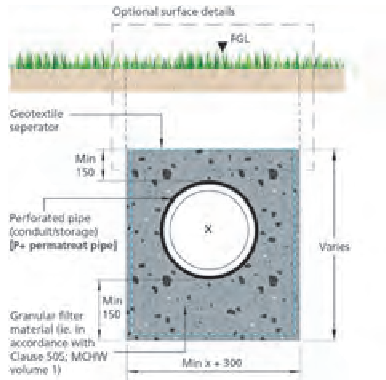


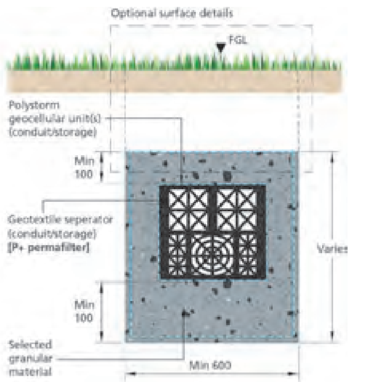
RIDGISTORM–XL
Can be used to partially replace granular material with proprietary pipe systems to increase the systems storage capacity typically without significantly increasing the system dimensions.

Ridgitreat 100-900mm (Section 4.2)
Can be used where additional hydrocarbon treatment is required.



Polystorm or Permavoid (Sections 2.4 and 2.5)
Can be used to partially replace granular material with propriety geocellular systems to increase the system storage capacity, typically without significantly increasing the system dimensions.

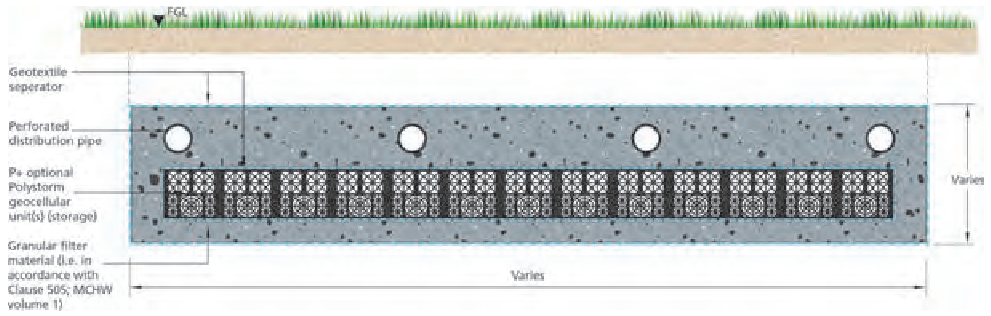




3.9.4 Infiltration blanket – infiltration: primary function

The granular material used to form the infiltration blanket may be replaced with proprietary unit(s) (i.e. larger diameter pipes or geocellular units) to increase the system's storage capacity, typically without significantly increasing the system dimensions.

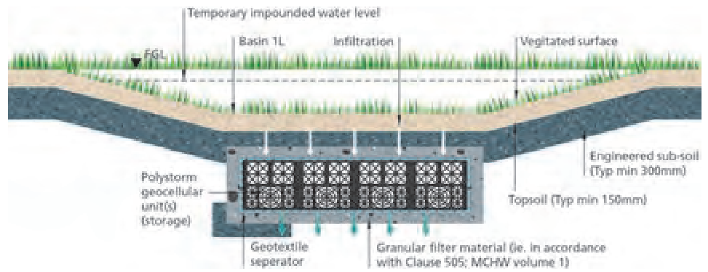
Where the blanket is used to provide water treatment, care should be taken to ensure that a sufficient depth of filter material is maintained to provide the expected level of water treatment.



3.9.5 Infiltration basin – infiltration: primary function

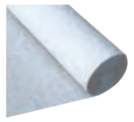
Where there is insufficient space available, or the system depth possible is limited due to the proposed location or non-drainage use (i.e. play area); additional, or longer term storage can be provided within the system by including an additional Polystorm/Permavoid geocellular installation beneath the basin invert.

The depth of the infiltration basin can also be reduced for the same storage possibly improving the Health & Safety of the feature. Permafilter geotextile can also be utilised to enhance hydrocarbon pollution treatment.

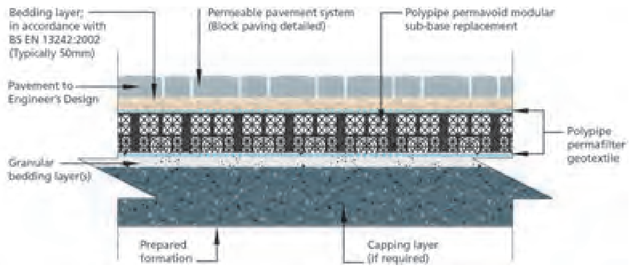


3.9.6 Permeable Pavement – infiltration: primary function

Permavoid geocellular unit (Section 2.4)
Where the thickness of the pavement sub-base is required to be increased to provide additional attenuation storage. The Permavoid unit may be used as a sub-base replacement; providing significantly higher storage capacity than an equivalent depth of granular sub-base material.



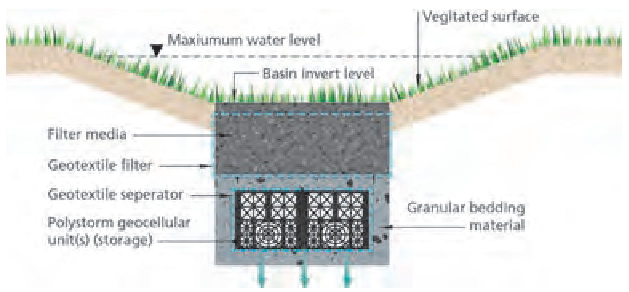
Permafilter (Section 2.4)
Proprietary geotextile designed to offer enhanced hydrocarbon pollution treatment; typically installed as part of a Permavoid sub-base replacement installation.

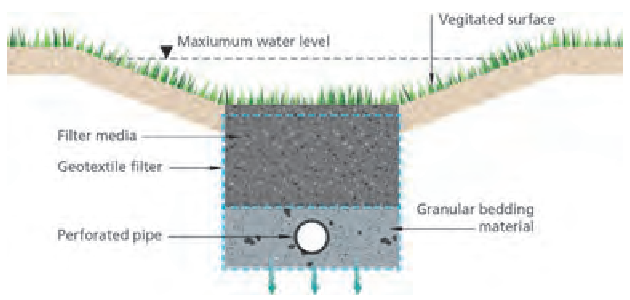


3.9.7 Swale – infiltration: secondary function

Some sections of the overall swale length may also be installed as an under-drained swale, offering a potential alternative to an above-ground outlet construction.

Polystorm geocellular unit (Section 2.5)
High porosity modular unit, providing significantly greater storage capacity compared with granular material requirements, in addition to reducing surrounding granular fill requirements.





Ridgidrain/Ridgistorm-XL/Ridgitreat perforated products can be used as an underdrain, providing significantly greater storage capacity compared with granular material, in addition to reducing surrounding granular fill requirements.

3.9.8 Conventional SuDS

Traditionally, infiltration systems were considered as the final element of a drainage system, receiving surface water run-off prior to discharge to ground (e.g. house soakaway).

However, a number of drainage systems can be designed to incorporate infiltration as an incidental function to the system's primary purpose (i.e. filter strip or unlined swale).

Determination of the soakaway characteristics required, can be summarised by the following basic calculation:

Inflow – Outflow = Storage requirement

Inflow

Surface water run-off received by the system; rate and total volume of inflow is dictated by the characteristics of the surface(s) being drained, drained surface area(s) and assumed rainfall characteristics of the design rainstorm event.

Hydraulic design – SuDS Manual (C753) guidance – Section 25.6

Outflow

Infiltration of surface water into the surrounding ground; rate and volume of water infiltrated into the ground is dictated by the infiltration characteristics of the soils surrounding the system, in addition to the surface area of the interface between the proposed drainage system and surrounding material(s).

Minimum soil infiltration rate is generally deemed to be 1 x 10-6m/s for a viable infiltration system.

However, a valuable contribution towards interception may still be possible at lower infiltration rates. A basic rule of thumb typically used to define interception being 'the prevention of surface water discharge from a development, due to the surface water run-off generated by an initial 5mm of rainfall'.

Source: The SuDS Manual (C753), Table 25.1

Drain time – SuDS Manual (C753) guidance – Section 25.7

Although an infiltration structure may still form the final element of a proposed drainage system, where there are multiple components to the SuDS design, there may be opportunities to include infiltration (as an incidental function) within the design of the constituent elements that form a developments SuDS treatment train.

Storage

The difference between the inflow and outflow volumes; the drainage system's dimensions are determined through an analysis of two associated system variables – the surface area over which infiltration is assumed to occur, in conjunction with the associated system water storage volume provided. Either system characteristic may dictate the final design of the proposed infiltration system, depending on the soil infiltration rate and design rainstorm event that is to be accommodated by the system.

It should be noted that part of infiltration design is to assess the time needed for a proposed structure to drain (typically half drain within 24hrs). This is to ensure that the system is able to accommodate concurrent rainstorm events.

Careful consideration should be given to the design rainstorm event used to undertake this check, to ensure that the design of the infiltration structure is not overly conservative.

Traditionally, stone rubble or aggregate has been used as the storage media in soakaways. Typically a void ratio of 30% is used.

Some drainage systems are typically designed with the primary function of infiltrating surface water run-off, some are designed with infiltration as a secondary function. In this instance the main objective may be to treat, transport or temporarily store surface water run-off. The design will be dependant on the suitability of the underlying ground conditions.

Although infiltration would not be the following system's primary design purpose, they can still make a valuable contribution to reducing the storage requirements within the drainage system, or provide interception of high frequency rainfall. It should be noted that where infiltration is proposed to form a secondary part of the system design, additional attention may need to be given to the specification of the underlying soils in order to minimise pollution risks.

3.9.9 - Soakaways – infiltration: primary function

A below-ground excavation, filled with a porous medium to increase the storage capacity of the installation. The size and extent of a soakaway can vary significantly from site to site.

Where the volume of the soakaway required becomes significant, it may be more economically and sustainably prudent to consider the introduction of additional elements within the system. With the aim of effectively increasing the system's overall porosity (storage capacity), without a significant increase in its overall dimensions.

Examples include:

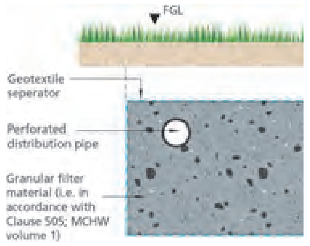
Chamber soakaways
Chamber(s) are installed within the excavation, which are surrounded by granular material. The size of the excavation is typically defined as a ratio of the chamber diameter; this can typically range from 1.5 to 3.0.

Geocellular proprietary units
Installed below ground to create a high porosity void. Depending on the proprietary unit, they would usually require a minimum volume of granular material and/or geotextile(s) to complete the installation.

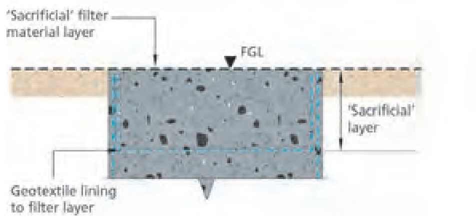
The system dimensions are generally in increments of the proprietary unit. There may also be limitations on how the proprietary units may be installed, requiring a site-specific structural assessment to be undertaken.

3.9.10 Trench – infiltration: primary function

Linear below-ground excavation (trench), filled with a porous medium to increase the storage capacity of the installation. Typically installed with a perforated pipe at the top of the trench, to ensure even distribution of water along the system.



A below-ground surface water conduit (i.e. pipe installation) may be converted to an infiltration trench, by using a perforated pipe.



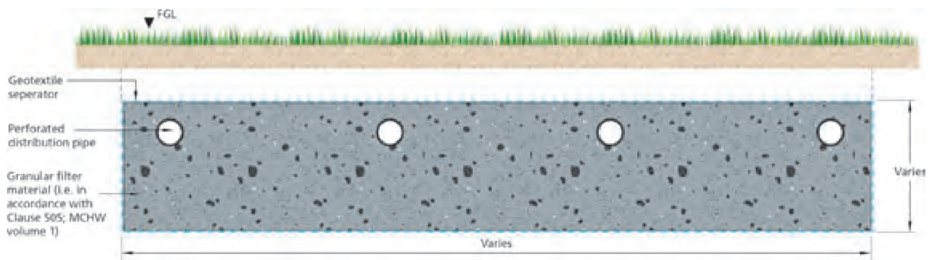
Alternative surface/backfill detail

For relatively small areas, infiltration trenches may be designed to collect surface water run-off, the backfill detail following that of a filter drain. In these instances the distribution conduit would typically be omitted.

3.9.11 Infiltration blanket – infiltration: primary function

Below ground installation, over a large plan area, typically consisting of a discreet layer of granular filter material. These systems are typically installed with a series of perforated distribution pipes within the top of the granular material, to ensure even distribution of surface water across the entire blanket plan area.

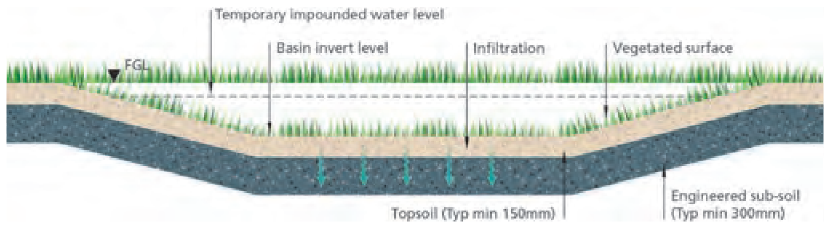
Infiltration blankets may be used to specifically provide water treatment; therefore ensuring water is distributed over the whole plan area to maximise the opportunity for bio-degradation of contaminants – while minimising the risk of sections of the system becoming overwhelmed.



3.9.12 Infiltration basin – infiltration: primary function

Surface landscaped depression, designed to allow infiltration (typically through the base) and temporary storage of surface water generated during a rainstorm event.

The profile of the depression sides can be varied to suit the landscape design. However, unless the system design includes specific landscaping or planting elements to prevent access, side slope gradients are typically formed at a maximum 1 in 3.



3.9.13 Permeable pavement – infiltration: primary function

Also refer to section 3.6

Pavements that are designed to allow surface water to percolate through the surface and underlying structural layers (including the formation soils, when designed to allow infiltration).

As part of the structural design, the depth of the pavement structural layer is determined through an analysis of the expected vehicle trafficking and strength of the sub-grade material (underlying native soils). With the hydraulic design, the depth of the granular sub-base material (specifically the material capable of storing surface water) is assessed to ensure it will provide sufficient storage. Where additional storage is required, the sub-base material depth may be increased (over the minimum structural requirement), or consideration given to the introduction of proprietary units that effectively increase the pavement's storage capacity.

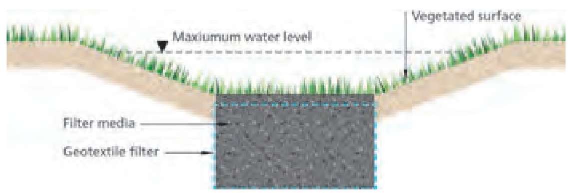
A permeable pavement system designed to allow infiltration into the underlying soils, can typically have a minimum construction depth of between 380 and 580mm (assuming a saturated sub-grade CBR ≥ 5%), depending on the category of vehicle trafficking expected. These depths may need to be increased where the supporting sub-grade material is weaker, or additional water storage capacity is required within the pavement structure.

3.9.14 Swale – infiltration: secondary function

Also refer to section 3.10

Where there is insufficient space available, or the system depth possible is limited due to the proposed location (i.e. adjacent to a vehicle trafficked area); additional, or longer term storage can be provided within the system by adapting the design as an underdrained (also known as 'dry' or 'enhanced') swale.

This is typically achieved by installing the swale with a permeable base, which may also include a conduit to encourage water flow to the downstream point of the swale. The depth of the permeable base can be increased to achieve a corresponding increase in the total storage capacity of the system; without a corresponding increase in land take, or increase in landscaped depression depth, that would normally be associated with increasing the capacity of a typical conveyance swale.



Dry swale

3.9.15 Hydraulic benefits

Where site conditions allow, infiltration systems are typically the preferred method to manage surface water run-off as they can significantly reduce, or even eliminate, the need for surface water discharge outside the development – assuming that a study of ground water levels, including an assessment of the impact of future infiltration across the development, concludes that ground water poses a negligible flood risk.

Extensive use of infiltration systems typically offer the lowest impact on the flood risk that a new development poses to adjacent sites. Where significant infiltration of surface water is not viable within the development, infiltration systems are still able to offer a number of hydraulic benefits. They may still be able to deliver interception of surface water run-off generated by the initial 5mm of rainfall during high frequency rainfall events. In addition, infiltration systems can reduce the total volume of surface water that may need to be discharged from the development. Where the predicted volume of surface water discharged from a development can be reduced to at least match pre-development discharge levels, the rate of discharge from a development (where the proposal is to discharge into a local river or water course) imposed by the regulating authority, will typically be less onerous. As a consequence, the total volume of surface water storage that may need to be provided within the development could be significantly reduced. Hydraulic design guidance is given within CIRIA C753 – SuDS Manual, Section 25.6. However, care should be taken when choosing the appropriate design guidance to follow when designing an infiltration structure, as the method of managing siltation risk may vary significantly.

For example:

- **BRE Digest 365**
  (Bias towards typical domestic installations) excludes infiltration through the base of the system
- **CIRIA Report 156**
  Uses a partial factor of safety, the magnitude of which is dictated by the siltation risk posed by the area being drained and the economic consequences if the structure were to fail – the factor applied to the infiltration rate(s) assumed for the surrounding ground conditions

Where an infiltration system is shallow relative to its plan area (i.e. typical Polystorm infiltration structure), a significant proportion of the infiltration from the system may be via the base. Therefore, use of the BRE Digest may lead to an overly conservative design, especially if other SuDS systems or controls to manage siltation are included within the drainage design upstream of the infiltration system.

Polypipe is able to offer a wide range of thermoplastic pipe and geocellular systems, including a comprehensive range of pipe diameters and associated fittings, that allow simple integration into drainage systems. Where the hydraulic capacity of the infiltration structure has been increased through the inclusion of perforated pipe(s), additional attenuation storage capacity may also be provided if these pipes are oversized. While Polystorm and Permavoid systems are modular, allowing the cross-section of an installation to be simply increased through the inclusion of additional units. Polystorm geocellular system units offer additional attenuation benefits, due to the unit's uniform shape and high porosity. Where the units are used in a continuous uninterrupted installation (i.e. along a trench), they can be assumed to act as a conduit, with flows typically driven by hydraulic head. It should also be noted that due to the internal structure of these units, they have a higher resistance to flows when compared with pipe systems. Therefore, they may offer an additional degree of flow attenuation, which could allow a reduction in the total water storage requirement within the drainage system.

3.9.16 Water treatment

When considering the use of infiltration systems within a development's drainage design, precautions should be taken to ensure that heavily polluted run-off is not discharged directly into the system. Uncontrolled discharge of silts and debris into an infiltration system can significantly affect the system's infiltration efficiency, as both the constituent porous media and geotextiles could become clogged. Consequently, this could reduce the design life of the infiltration system, or require frequent unplanned maintenance activities to be undertaken.

Unless the infiltration system has been designed to treat a specific pollutant within the system (i.e. drainage blanket; with detailed filter material specification), careful consideration of the composition and condition of the surrounding soils and ground water levels should be undertaken to ascertain the:

- ability of the material to attenuate pollutant(s)
- potential resident time of the pollutant(s) within the material, prior to its discharge to a water body
- ability of the material to support microbe colonies that can biodegrade the pollutant(s)

The ability of the system to reduce a pollutant to environmentally acceptable levels, with the subsequent residual pollution risk that the infiltration structure potentially poses, may then be quantified. Reference to the risk matrix, used as part of the risk screening methodology, provides guidance on the soil parameters used to qualify the potential pollution risk that an infiltration system poses.

Risk Matrix Table – Risk Screening Methodology (Abridged)

Element Description	System Element Risk Scores		
	Low Risk	Medium Risk	High Risk
Unsaturated zone depth (distance between system invert and ground water table)	> 15m	5 – 15m	1 – 5m
Predominant flow type through underlying soils	Intergranular flow (non-fractured deposits and fine or medium sands)	Mixed fracture and intergranular flow (fractured consolidated deposits and medium or coarse sands)	Fractured flow (heavily consolidated sedimentary deposits and very coarse sand)
Unsaturated zone organic carbon content	> 15%	1 – 15%	< 1%
Unsaturated zone, soil pH	> 8	5 - 8	< 5

Note: Table is an abridged reproduction of Table 26.5, The SuDS Manual (C753)

For groundwater risk screening see – SuDS Manual (C753) guidance – Section 26.7.2; Table 26.5, Risk matrix

The exact construction of an infiltration structure and the site conditions therefore influence the effectiveness of an infiltration system in attenuating or treating pollutants. Various options are available to the designer to enhance the ability of infiltration structures to treat surface water, such as the careful specification of engineered materials used, or inclusion of filter geotextile layer(s) within the installation.

As noted in Section 3-3-3, particular consideration should be given to the silt load that may be entrained within the surface water that discharges into an infiltration device. Silt typically being the main pollutant that could limit the design life of an infiltration system, or increase maintenance costs. This can be managed through careful design of the development's SuDS treatment train, upstream of the infiltration device, or the introduction of sacrificial elements to facilitate future maintenance and minimise costs.

3.9 Infiltration Systems

Typical Infiltration Coefficients Based on Soil Texture (Amended from Bettess, 1996)

Soil type/texture	ISO 14688-1 description (after Blake, 2010)	Typical Infiltration Coefficients (m/s)
Good infiltration media		
Gravel	Sandy gravel	$3x10^{-4}$ to $3x10^{-2}$
Sand	Slightly silty slightly clayey SAND	$1x10^{-5}$ to $5x10^{-5}$
Loamy sand	Silty slightly clayey SAND	$1x10^{-4}$ to $3x10^{-5}$
Sandy loam	Silty clayey sand	$1x10^{-7}$ to $1x10^{-5}$
Poor infiltration media		
Loam	Very silty clayey SAND	$1x10^{-7}$ to $5x10^{-6}$
Silt loam	Very sandy clayey SILT	$1x10^{-7}$ to $1x10^{-5}$
Chalk (structureless)	n/a	$3x10^{-8}$ to $3x10^{-6}$
Sandy clay loam	Very clayey silty SAND	$3x10^{-10}$ to $3x10^{-7}$
Very poor infiltration media		
Silty clay loam	--	$1x10^{-8}$ to $1x10^{-6}$
Clay	--	$< 3x10^{-8}$
Till	Can be any texture of soil described above	$3x10^{-9}$ to $3x10^{-6}$
Other		
Rock*(note mass infiltration capacity will depend on the type of rock and the extent and nature of discontinuities and any infill)	n/a	$3x10^{-9}$ to $3x10^{-5}$

The Permafilter geotextile is specifically designed to treat hydrocarbons within surface water flows. Permafilter is a dimpled, non-woven needle-punched geotextile, comprising a proprietary blend of hydrophilic and hydrophobic fibres.

The proprietary blend of fibres is designed to retain hydrocarbons on the geotextile; in addition to maintaining a level of moisture that encourages biofilm formation and subsequent aerobic biodegradation of the retained hydrocarbons. There have been extensive installations of planar infiltration systems that incorporate Permafilter – in particular, permeable pavements.

Although the Polypipe surface water conduit and storage products summarised in this section may not directly offer significant additional water treatment benefits, they can be used to manage the maximum water flows through other SuDS elements. This enables the treatment efficiency of the other SuDS elements within the treatment train to be maximised. They can also enable the choice of SuDS options available to a Designer to be maintained, even on constrained sites where space availability may otherwise be used to excuse their exclusion.

Installation of Polypipe's range of associated fabrication chambers can be used to facilitate the inspection and maintenance of infiltration systems, particularly where they extend over a significant distance or interface with other drainage systems.

For more information please refer to:
The SuDS Manual (C753), Section 13: Infiltration Systems.

Mendora Road, Permeable Pavement – Infiltration

INTRODUCTION
3.1 BLUE-GREEN ROOFS
3.2 PODIUM DECKS
3.3 TREES
3.4 SPORTS PITCHES
3.5 CYCLE PATHS
3.6 PERMEABLE PAVEMENTS
3.7 BIORETENTION SYSTEMS
3.8 ATTENUATION STORAGE TANKS
3.9 INFILTRATION SYSTEMS
3.10 SWALES
3.11 FILTER DRAINS
3.12 DETENTION BASINS
3.13 PONDS AND WETLANDS
3.14 FILTER STRIPS

3.10 Swales

Swales are shallow vegetated open channels. They can be natural, but within a developed environment they're usually designed as part of an engineered SuDS scheme.

Typically featuring a wide-bottomed trapezoidal or parabolic cross-sectional profile for ease of maintenance and construction, the design also offers good hydraulic performance when combined with engineered SuDS systems. Polystorm geocellular units installed below the swale, for example, provide greater storage and attenuation capabilities. The system can be further enhanced for water treatment by installing Permafilter or Ridgitreat.

However, swales are generally used to facilitate the collection of distributed surface water run-off from long linear surface areas (e.g. paths, car parks and roads) to convey and treat surface water over, and infiltrated through, its vegetated surface, whilst attenuating naturally. Based on their form of construction, swales can be classified as:

- Dry or enhanced swales
- Conveyance and attenuation swales
- Wet swales

During extreme rainwater events and/or where a proposed swale follows a steep gradient, berms, check dams or weirs may be incorporated within the swale channel. The flow velocity is reduced, whilst the discrete 'bays' that are created within a swale may be used to capture and retain accidental pollution spills to a localised area of the system. This allows simple identification of accidental spills, facilitating its clean-up and minimising any resultant remedial work that may be required. Slowing the travel of water in this way also allows the swale to store and attenuate the water at a preferred rate.

Indicative Treatment Efficiency	
Pollutant	**Reduction: Inlet to Outlet**
Dissolved Copper	50%
Dissolved Zinc	50%
Suspended Solids	80%

Data source – DMRB; HD 33/16; Table 8.1

In the event of a spillage, the maximum reduction of spillage risk considered achievable:

Optimum Risk Reduction Factor RF 0.6 (40%)

Multifunctional benefits of swales

MAKING SPACE FOR WATER
Enhanced storage capacity by integrating geocellular or pipe solutions.

SURFACE WATER MANAGEMENT
Site level flow control and conveyance.

WATER QUALITY
Water treatment offered via lateral flow of water through the vegetation in the swale. Enhanced with the inclusion of treatment geotextiles.

ASSET CREATION
Addition of gardens/green spaces can increase the aesthetic look of an area adding value to the property/development.

AMENITY
Enables easy integration into various designs, provides aesthetics, increase in vegetation, adds water treatment.

BIODIVERSITY
Swales can include a variety of planting which can make a positive contribution to urban biodiversity.

EVAPORATIVE COOLING
Swales provide cooling via return of moisture to the air through evaporation/evapotranspiration from vegetation. Can reduce local temperatures. Can also reflect sunlight.

PLACEMAKING
Creating attractive green spaces in urban areas that wouldn't usually be available.

3.10.1 Dry or enhanced swales

Where there is insufficient space available, the swale system depth is typically limited due to the proposed location (i.e. adjacent to a vehicle trafficked area), or a deep inlet needs to be integrated into the swale.

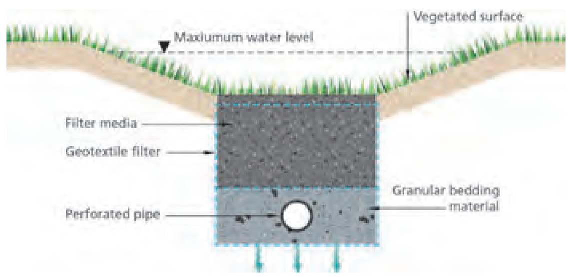
Where the swale surface channel has a permeable base, an under drained (also known as 'dry' or 'enhanced') swale may be installed, with a layer of filter material installed below it. The filter material would typically include a conduit to encourage water flow to the downstream discharge point, into which, deep inlet pipes may also be incorporated. Where a below ground conduit receives direct inflows (i.e. via pipe connection), careful design of the overlying medium or control features would still allow the surface channel to provide attenuation storage during high rainfall events.

The depth of the permeable base construction may be increased to achieve a corresponding increase in the total storage capacity of the system; without a corresponding increase in land take, or increase in landscaped depression depth, which would normally be associated with increasing the capacity of a typical conveyance swale.

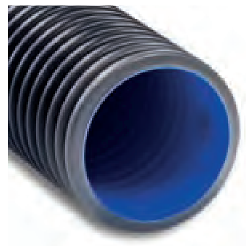
Increasing storage in swales – hydraulic benefits

An enhanced swale can be achieved by increasing the diameter of the perforated Ridgidrain pipe or substituting the pipe with a geocellular unit which would still allow flows along the swale (behaves like a conduit).

Polypipe is able to offer a wide range of thermoplastic pipe systems, including a comprehensive range of pipe diameters and fittings, allowing simple integration into the drainage system. Where the hydraulic capacity of the swale has been increased through the provision of a granular filter layer below the swale invert (i.e. dry or enhanced swale), additional attenuation storage capacity may be provided by oversizing the conduit pipe which is typically installed within the granular layer.



Dry swale

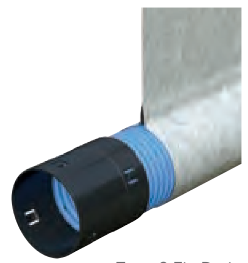

Ridgidrain


Landcoil

Ridgidrain
Thermoplastic structured walled surface water drainage system. Available as half perforated and fully perforated pipe in diameters 100-900mm, 6m in length, lighter in weight.

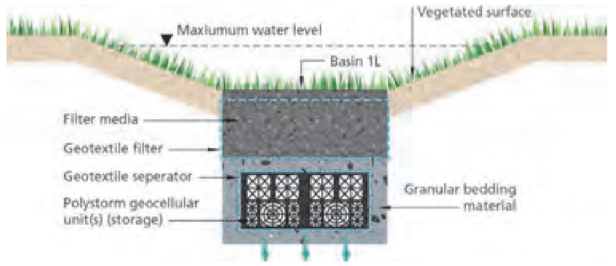
Landcoil
PVCu single walled flexible pipe land drainage system. Available in diameters 60-200mm.

Linflex Type 6 Fin Drain and Type 8 Filter Drain
PVCu single walled flexible pipe land drainage system pre-wrapped in geotextile. Linflex Type 6 Fin Drain available in diameters 80-160mm, Linflex Type 8 Filter Drain available in diameters 60-160mm.


Type 6 Fin Drain


Type 8 Filter Drain

Substitution of the underdrain pipe with a Polystorm geocellular system unit, would offer additional attenuation benefits, due to the unit's uniform shape and high porosity. The geocellular units can also behave as a conduit, provided a continuous installation is maintained along the trench, with flows typically driven by hydraulic head.



Enhanced swale

A limited section of the overall swale length may also be installed as an under drained swale, offering a potential alternative to above ground outlet construction.

Polypipe Geocellular Products					
Code	Description	Length (mm)	Width (mm)	Depth (mm)	Storage per m
PSM1A	400mm Polystorm Unit	1000	500	400	0.19
PSM3	200mm Polystorm Unit	1000	500	210	0.105
PVPP85	85mm Permavoid Unit	708	354	85	0.021
PVPP150	150mm Permavoid Unit	708	354	150	0.038

This form of construction may also be used with steeper gradient swales, provided appropriate flow controls are used at intermediate points along the swale. Where berms or check dams are proposed to be installed within the swale channel, the below ground control elements would typically coincide with the location of these surface channel features.

Polypipe is able to offer a range of pre-fabricated chambers, designed to facilitate the simple inclusion of a range of flow controls in the drainage system. A number of Polystorm and Permavoid geocellular units are also available to control water flow.

RIDGISTORMCheck Vortex Flow Control

Treatment in swales – treatment benefits

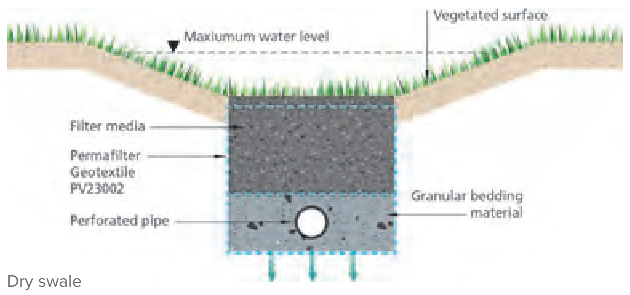
Where a dry swale is installed with a pipe within the granular material, the effectiveness of the pipe and filter material in treating hydrocarbons can be increased, through the direct substitution of the pipe with:

Ridgitreat

Permafilter geotextile-wrapped perforated pipe system; designed to catch, filter and facilitate the break down of hydrocarbons. Available in 100-300mm pipe diameters.

Where a geotextile filter material is used within the system construction, Polypipe can offer proprietary Permafilter geotextile, which is specifically designed to treat hydrocarbons within surface water flows.

Permafilter is a dimpled, non-woven needle-punched geotextile, comprising a proprietary blend of hydrophilic and hydrophobic fibres. The proprietary blend of fibres is designed to retain hydrocarbons on the geotextile; in addition to maintaining a level of moisture that encourages biofilm formation, and subsequent aerobic biodegradation of the retained hydrocarbons.



Dry swale

Installation of Polypipe's range of associated fabrication chambers facilitate the inspection and maintenance of the filter drain system, particularly where they extend over a significant distance.

RIDGISTORMSeparate Catchpit

3.10.2 Conventional SuDS _ typical construction

A typical swale design consists of a grassed channel with:

- A base width of 0.5-2.0m
- Side slopes with gradients between 1 in 3 - 1 in 4
- A maximum depth of 400-600mm

The longitudinal slope of a swale should be constrained to 1 in 17 (6%) to 1 in 200 (0.5%) to control the flow velocity along the swale, to levels that minimise the risk of erosion and maximise treatment efficiency. Where the gradient across a site would result in longitudinal slopes:

- Steeper than 1 in 34 (3%), the installation of berms or check dams within the channel should typically be considered to control flow velocity along the swale
- Shallower than 1 in 66 (1.5%), consideration should be given to the installation of an enhanced (underdrained) or wet swale, which are better able to manage very low velocity flows

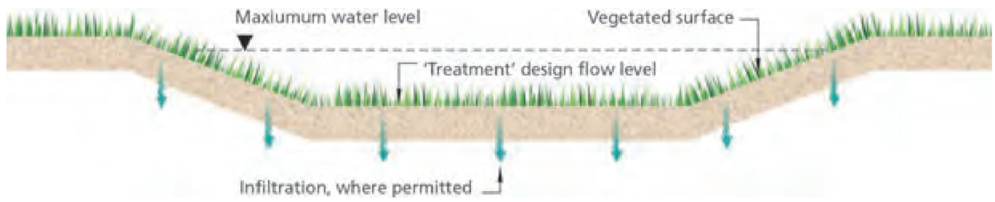
Where the swale is designed to receive a lateral distributed surface water inflow, from an adjacent linear surface, an attempt should be made to minimise the channel side slope over which the water will flow as far as possible. Maximising the water treatment efficiency of the system, while also marking maintenance operations (i.e. mowing grass) easier. Where space restrictions may require steeper channel sides, these can be successfully created through the careful design of landscape features that either form part of the channel itself (i.e. wall) or run adjacent to the system. The use of non-uniform or deeper swale channels would typically require a more detailed analysis of the expected flow depth, velocity and water treatment efficiency to be undertaken.

If point inflows are required to be incorporated into a conveyance swale construction, at a depth that is below the ideal maximum surface channel depth, an enhanced swale that incorporates the point inlet into a below ground conduit could be used. However, it should be then noted that the water inflow into this conduit would not receive the same level of water treatment, compared with flows travelling along the swale surface channel. Swales can be designed to allow infiltration through the channel faces. However, where the ground conditions are not conducive to infiltration, or it would pose an unacceptable pollution risk (e.g. within a brown field or industrial site), the swale channel can be lined with an impermeable membrane.

3.10.3 Conveyance and attenuation swales

Typical conveyance swales are usually shallow vegetated open channels, with the vegetation typically grasses.

A limited section of the overall swale length may also be installed as an under drained swale, offering a potential alternative to an above ground outlet construction.



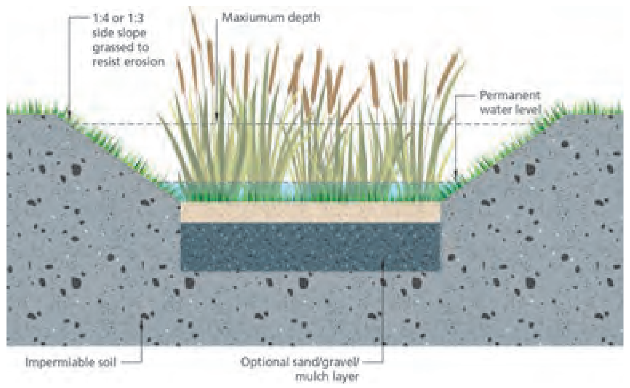
Typical conveyance/attenuation swale

3.10.3 Wet swales

Designed to behave in a similar manner to conveyance swales, wet swale systems provide wet or marsh conditions at the channel base. As a result, the planting at the swale base would typically be similar to that used for pond or wetland systems.

Wet swale systems are typically used where:

- Only shallow longitudinal gradients are possible (i.e. less than 1 in 66 (1.5%))
- Underlying soils are impermeable
- Specific biodiversity objectives are better met by wetland type systems



Source: The SuDS Manual (C753), Fig 17.3

3.10.4 Channel vegetation

The type, density and height of vegetation (especially vegetation incident to water flow) can have a significant effect on the hydraulic performance characteristics of the swale.

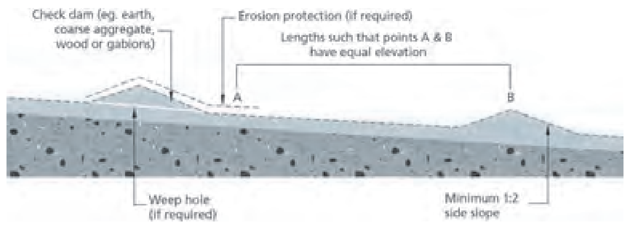
For a typical conveyance swale water flow design depth of 100mm, the ideal vegetation depth that should be maintained is normally considered to be 75-150mm. Wet swales, or swales specifically designed to convey significantly deeper flows, would typically require wetland type planting.

For more information please refer to:
The SuDS Manual (C753), Section 17: Swales.

3.10.5 Channel berm of check dam installation

Where the hydraulic design has identified the need for the installation of berms or check dams within the channel, they may be formed using a variety of landscaped features, including:

- Earth/granular material berms
- Stone walls
- Gabions
- Wooden boards
- Stone boulders



Source: The SuDS Manual (C753), Fig 17.3

Typically, berms are installed at 10-20m intervals, with a minimum height corresponding with the crest of the berm coinciding with the level of the upstream berm toe.

Consideration should also be given to the installation of appropriate erosion protection measures, or techniques for the dissipation of flow energy. This includes protection of berm and channel surfaces, or areas immediately around any zone where flows are expected to be channelized, such as opening within check dams. With the protection measure typically extended 1.0-2.0m beyond the downstream face of the berm.

3.10.6 Hydraulic benefits

While a primary purpose of a swale system is to act as a surface conveyance system, they can also provide the following hydraulic benefits:

- Interception and infiltration – reducing the volume of surface water that may need to be discharged from the development, through:
  - Infiltration into the underlying soils, when feasible
  - Attenuation within the soil matrix that supports the vegetated surface, and via evapotranspiration
- The provision of surface attenuation storage capacity
- Reduces the total attenuation storage requirements of a development, as flow rates through swales tend to be slower than conventional below ground systems; due to the higher surface roughness of a typical swale channel

However, a swale hydraulic design would also need to consider the occasionally conflicting performance requirements of maximising water treatment efficiency, while maintaining peak channel flow capacity.

Maximum water treatment efficiency is typically achieved when surface water flow velocities generated from a 1 in-1 year (100% probability) rainstorm event, is restricted to 0.3 m/s – and a minimum water flow resident time, within the swale channel, of at least 9 minutes is achieved.

Channel water velocities below 1.0m/s should be maintained, unless specific protective measures are undertaken, to prevent erosion of vegetative surfaces during extreme rainstorm events.

Where the hydraulic design identifies that there is a need to increase the swale capacity, it is typical practice to increase the base width, as opposed to the channel depth. Thereby limiting any increase in flow velocity and depth, which would have a detrimental effect on the swale system performance.

Based on open channel flow theory, expected flow depth and velocity within the channel are analysed – Manning's equation typically being used to predict the flow characteristics through swale channels.

The calculation variables that dictate the expected swale channel hydraulic performance being:

- Swale cross sectional area
- Channel perimeter; face length which will contain the flow
- Swale longitudinal gradient
- Expected roughness of the channel surfaces, including the type and height (seasonal variable) of channel vegetation

Source: The SuDS Manual (C753) Section 24.11

When using the Manning's equation, the channel roughness is represented by a roughness (Manning's) co-efficient, 'n'. It should be noted that the roughness co-efficient can vary with water depth – which can have a significant effect when considering a relatively shallow water flow passing over submerged vegetation (i.e. conveyance swale), or with flows passing through emergent vegetation (i.e. wet swale wetland planting).

Where there are significant differences in the surface characteristics across the swale channel, such as between the side slopes and base (i.e. enhanced swale), an 'aggregated' roughness co-efficient can be calculated.

3.10.7 Water treatment

A significant reduction in the potential pollution impact of surface water run-off can be obtained through the attenuation of run-off generated by high frequency rainfall events, typical approximated by a 5mm rainfall depth.

Swales can offer opportunities to provide interception, through:

- Infiltration into the underlying soils, where technically feasible
- Attenuation within the soil matrix that supports the surface planting/vegetation, and evapotranspiration

Further water treatment can also be achieved by ensuring low water flow velocities through the channel surface vegetation and the depth of flow does not significantly exceed the vegetation height. Optimum treatment efficiency is typically achieved when an approximate maximum water flow velocity of 0.3 m/s is maintained. This enables the following treatment mechanisms to remove:

- Coarse sediments, via filtration through the surface vegetation
- Fine sediment, via sedimentation; with low flow velocities and a minimum retention time within the swale, promoting the deposition of silts entrained within the surface water run-off
- Nutrient sand dissolved metals, through biodegradation and plant uptake
- Chemical compounds, by photolysis and volatilisation

Where a point inflow is connected directly into the conduit of a dry swale, the treatment of this surface water would be significantly reduced, due to the water flow effectively by-passing the vegetated surface channel. However, fine silt particles and other pollutants can still be removed through sedimentation and sorption within the filter material. Therefore, where these below ground point inflow connections are made, careful consideration should be given to the other SuDS components used within the proposed drainage system design to maintain the overall level of water quality treatment.

It should be noted that when considering surface water run-off from extreme events, which typically have a limited pollution impact due to the higher levels of dilution, consideration should be given to exceedance flow routes that by-pass the swale. This will help to minimise the risk of the treatment capability of the swale being overwhelmed, pollutants being re-entrained within the exceedance flows or causing damage to the vegetation cover.

3.11 Filter Drains

Also referred to as French Drains, Filter Drains are shallow linear trenches filled with granular filter material. They can be used to create temporary subsurface storage for the attenuation, conveyance and filtration of surface water run-off – usually receiving lateral inflow from an adjacent impermeable surface that has been pre-treated via a filter strip.

Indicative Treatment Efficiency	
Pollutant	**Reduction: Inlet to Outlet**
Metals	7%
Polyaromatic Hydrocarbons (PAH)	52%
Total Suspended Solids (TSS)	38%

Data source – DMRB; HD 33/16

In the event of a spillage, the maximum reduction of spillage risk considered achievable:

Optimum Risk Reduction Factor RF 0.6 (40%)

Multifunctional benefits of filter drains

MAKING SPACE FOR WATER
Enhanced storage capacity by integrating geocellular or pipe solutions.

SURFACE WATER MANAGEMENT
Conveyance & storage at source.

WATER QUALITY
Water treatment via aggregate, treatment geotextiles at source.

3.11.1 Polypipe GI solution – pipes in filter drains

Inclusion of a perforated pipe at the invert of an infiltration trench assists in draining of the trench. Polypipe is able to offer a number of product ranges that can be used for this application.

Ridgidrain

Landcoil

Ridgidrain

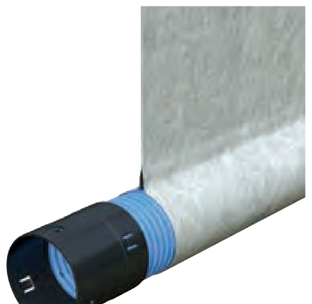
Thermoplastic structured walled surface water drainage system. Available as carrier, half perforated and fully perforated pipe in diameters 100-900mm, 6m in length, lighter in weight.

Landcoil

PVCu single walled flexible pipe land drainage system. Available in diameters 60-200mm, in coils up to 150m, lighter in weight.

Linflex Type 6 Fin Drain and Type 8 Filter Drain

PVCu single walled flexible pipe land drainage system pre-wrapped in geotextile. Linflex Type 6 Fin Drain available in diameters 80-160mm, Linflex Type 8 Filter Drain available in diameters 60-160mm.



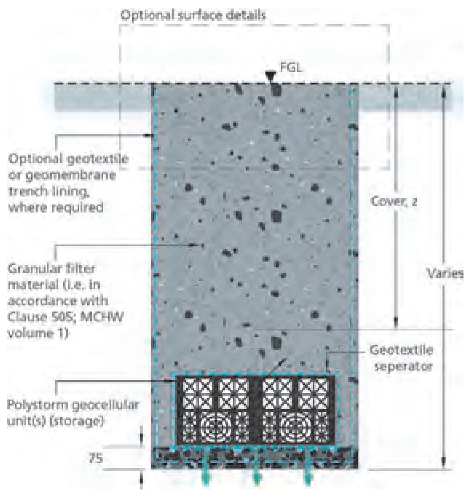
Type 6 Fin Drain

Type 8 Filter Drain

3.11.2 Geocellular products in filter drains

In instances where the infiltration trench is only acting as a collector, provided appropriate flow controls are included downstream in the drainage system, consideration may also be given to increasing the potential attenuation storage provided by the infiltration trench.

This increase in attenuation storage can be achieved through either increasing the diameter of the pipe (oversize) installation at the trench invert, or substituting the pipe for a geocellular unit from our Polystorm product range. Where the units are used in a continuous installation along the trench, they would also behave as a conduit, with flows typically driven by hydraulic head.



Polypipe Geocellular Products					
Code	**Description**	**Length (mm)**	**Width (mm)**	**Depth (mm)**	**Storage per m**
PSM1A	400mm Polystorm Unit	1000	500	400	0.19
PSM3	200mm Polystorm Unit	1000	500	210	0.105
PVPP85	85mm Permavoid Unit	708	354	85	0.021
PVPP150	150mm Permavoid Unit	708	354	150	0.038

Polypipe is able to offer a range of pre-fabricated chambers, designed to facilitating the simple inclusion of a range of flow controls in the drainage system.

3.11.3 Treatment in filter drains

Where an infiltration trench is installed with a pipe at the trench invert, the effectiveness of the infiltration trench in treating collected surface water can be increased through the use of a type 8 filter drain, or enhanced even further by wrapping the pipe in permafilter.

This can be done in situ with rolls of Permafilter: Product code PV23002 or pre wrapped.

Ridgitreat

Permafilter geotextile-wrapped perforated pipe system; designed to catch, filter and facilitate the break down of hydrocarbons. Available in 100-900mm pipe diameters.

Ridgitreat Plain Ended Pipes			
Code	**ID (mm)**	**Length (mm)**	**Weight (kg)**
RDT100X6PEP	100	6	5
RDT150X6PEP/1	150	6	7.5
RDT225X6PEP/1	225	6	15
RDT300X6PEP/1	300	6	25.5

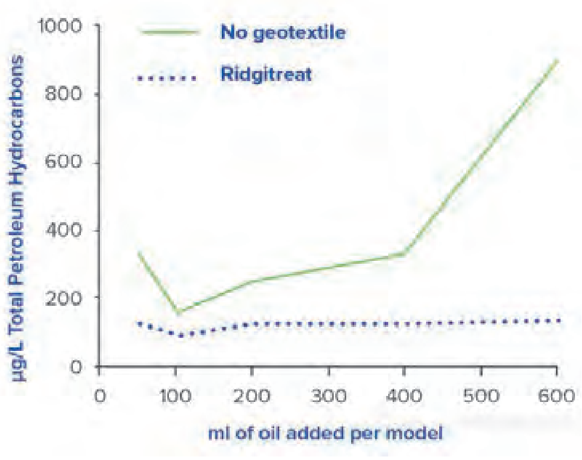
Permafilter geotextile-wrapped perforated pipe

3.11.4 Treatment benefits

The Permafilter geotextile is specifically designed to treat hydrocarbons within surface water flows. Permafilter is a dimpled non-woven needle-punched geotextile, comprising a proprietary blend of hydrophilic and hydrophobic fibres.

The proprietary blend of fibres is designed to retain hydrocarbons on the geotextile; in addition to maintaining a level of moisture that encourages biofilm formation and subsequent aerobic biodegradation of the retained hydrocarbons.

Ridgitreat uses the Permafilter geotextile to form a sawn sock, the ends of which are sealed to the perforated pipe. When jointed with the associated ring seals and double socketed couples Ridgitreat offers guaranteed system integrity. Work undertaken by Coventry University's SuDS Applied Research Group has shown that Ridgitreat is able to offer additional protection against hydrocarbons.[1]



Source: Coventry University's SuDS Applied Research Group

For more information please refer to:
The SuDS Manual (C753), Section 16: Filter Drains.

Sample Petroleum Hydrocarbon Concentration [μg/L]

Test	Mean	Maximum
No geotextile	357	770
Ridgitreat	143	221

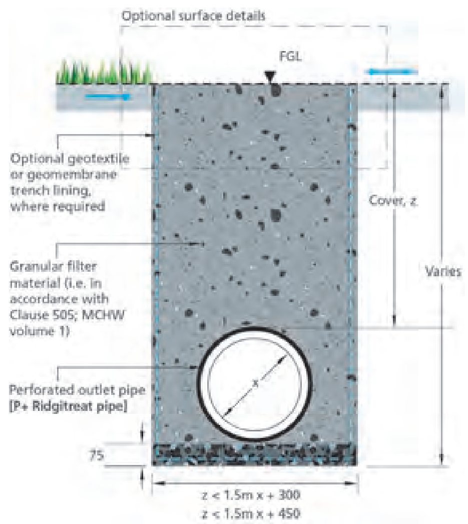
Source: Coventry University's SuDS Applied Research Group

3.11.5 Conventional SuDS – typical construction

Filter drains would typically be expected to form the initial drainage element (collector) at the head of a SuDS Treatment Train. Where space allows, they may also initially be protected from silt by a filter strip (Refer to Section 3.14).

Filter drains have been used extensively on the road network, particularly in rural areas, due to their linear nature and the relatively small plan area needed to install them.

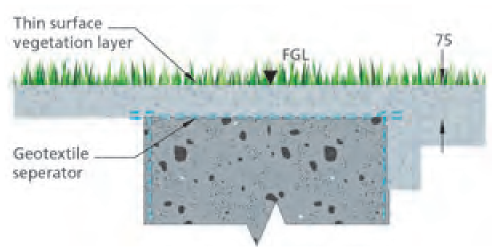
It should be noted, when considering the drainage of roads there are specific requirements, to ensure that the integrity of the pavement structure is maintained and no additional safety risks for road users are introduced. Consequently, there is extensive guidance available on the design and installation of filter drains alongside roads. Including publications by the various organisations responsible for both the national and local highway and road networks.



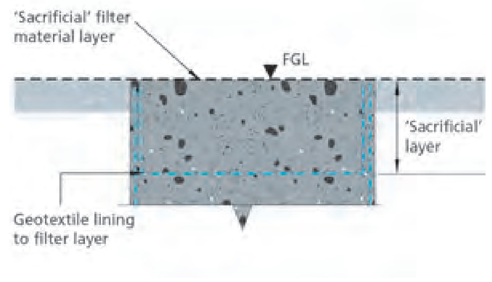
Typical filter drain construction

1. Newman, A. Nnadi, E.O. Mbanaso, F.U. (2015) Evaluation of the effectiveness of wrapping filter drain pipes in geotextile for pollution prevention in response to relatively large oil release. In: Karvazy, K. Webster, V.L. ed. World Environmental and Water Resources Congress, May 17–21, 2015, Austin, Texas. American Society of Civil Engineers; pp. 2014-2023.

A key consideration when used adjacent to roads, would be the likelihood of the trench surface being accidentally trafficked and subsequent scattering of the granular filter material. To limit the risk of this, stabilisation of the granular material at the trench surface may be undertaken, i.e. through the use of a geogrid, bonding agent or establishment of a thin surface vegetation layer. Certain installations may also require the inclusion of an impermeable trench liner (i.e. geomembrane), where the infiltration trench effectively abuts the road construction and additional protection against water ingress is deemed necessary.



Thin vegetative surface



Sacrificial filter layer with geotextile lining

3.11.6 Hydraulic benefits

Infiltration trenches may be designed to allow infiltration into the surrounding soils.

Where significant infiltration of surface water is not viable, infiltration trenches are still able to offer a number of hydraulic benefits. Surface water entering the drainage system is slowed, due to it having to percolate through the granular filter material. They may also assist in contributing to interception storage, as the granular material offers a significant surface area that would need to be 'wetted out' prior to water draining from the filter drain.

The filter material within an infiltration trench can also be expected to have a minimum porosity, offering a degree of attenuation storage at the head of a drainage system. Filter material porosity can typically vary between 30-50%, with 30% typically assumed for design purposes if detailed information on the material is not available.

The drainage of the trench can be facilitated with the inclusion of a perforated pipe at the trench invert. Perforated pipe may also be installed near the trench surface, to act as an overflow – where the increased management of surface ponding risk is required, for example.

3.11.7 Water treatment

Filter trenches are typically used as an initial surface water 'collector' at the upstream end of a drainage system, offering protection against debris from entering the drainage system, in addition to providing a degree of filtration of silts and hydrocarbons.

The exact construction of a filter trench can influence its effectiveness in filtering silt and hydrocarbons, with various options available to the Designer; such as the inclusion of a sacrificial geotextile layer beneath the trench surface.

Silts are typically deposited within the granular filter material, as water percolates through the material voids. Whilst the treatment of hydrocarbons within a filter trench, is typically dependent on sorption with the filter material particles, or retention on geotextile(s) where used.

3.12 Detention Basin

Detention basins are surface landscaped depressions that are designed to provide stormwater attenuation storage during high intensity rainfall events.

Landscaping of detention basins may consist of vegetation or hard landscaping elements; however, hard landscaping is more typically used in high density urban environments, where the system serves a specific secondary amenity purpose (i.e. seating and high use recreational space).

Applicable to most development types, detention basins may be retrofitted within existing drainage systems, provided the level of the existing drainage network and space available allows. Detention basins are utilised in a similar manner to attenuation storage tanks, in that they typically provide temporary stormwater attenuation storage during high intensity rainfall events – prior to infiltration, the stored water being reused, or discharged in a controlled manner. Until the system's attenuation storage is required, detention basins are typically designed to remain dry. As with attenuation tanks, detention basins may be integrated into the drainage system, either in an on-line or off-line arrangement (refer to section 3.8.2); where the following terms are pertinent:

On-line

Used to denote that all of the flow is passing through the drainage system and also flows through the detention basin. An appropriately designed flow control(s) is typically integrated within the drainage system, immediately downstream of the detention basin. This allows a controlled flow of water from the detention basin and enables the utilisation of the system's attenuation storage to be maximised during high intensity rainfall.

Off-line

Typically used to denote that during normal operation of the drainage system, flow generated by low intensity rainfall by-passes the detention basin system; the basin's attenuation storage capacity only being utilised during conditions caused by higher intensity rainfall. This is typically managed with the integration of appropriately designed flow control(s) within the drainage system, diverting flows into the attenuation storage tank, then allowing a controlled release from the attenuation storage back into the drainage system when conditions permit.

Drainage designers can use detention basins to enable other SuDS elements within a drainage system to be optimised. This is to achieve the maximum level of water treatment, whilst protecting the system from being overwhelmed during high intensity rainfall. Detention basin themselves, also offer a means of:

- Volume and flow rate control

Where the basin is planted with vegetation, careful design and analysis of surface water flows through the detention basin system enables the system to offer the following additional benefits:

- Interception
- Infiltration
- Pollution treatment
- Cooling effects around the system; via evapotranspiration

(SuDS Manual (C753) guidance – Chapter 12)

Indicative Treatment Efficiency

Pollutant	Reduction: Inlet to Outlet
Dissolved Copper	0%
Dissolved Zinc	0%
Suspended Solids	50%

DMRB; HD 33/16; Table 8.1

In the event of a spillage, the maximum reduction of spillage risk considered achievable:

Optimum Risk Reduction Factor RF
0.6 (40%) (when used as an on-line system)

Multifunctional benefits of detention basins

MAKING SPACE FOR WATER
Enhanced storage capacity by integrating geocellular or pipe solutions.

EVAPORATIVE COOLING
Detention basins can provide cooling via return of moisture to the air through evaporation/evapotranspiration from vegetation. Can reduce local temperatures. Can also reflect sunlight. When full the water will also evaporate from the surface.

BIODIVERSITY
Detention basins can include a variety of planting which can make a positive contribution to urban biodiversity.

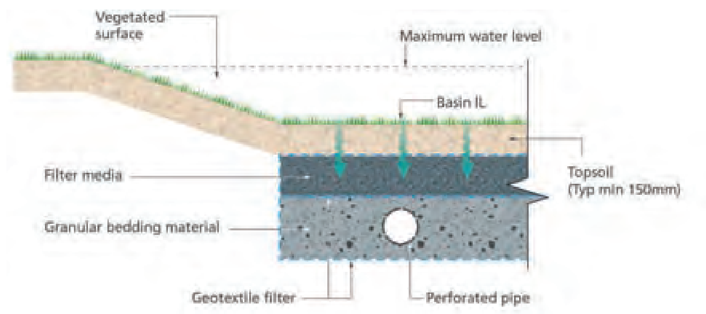
SURFACE WATER MANAGEMENT
Site level flow control.

PLACEMAKING
Creating attractive green spaces in urban areas that wouldn't usually be available.

3.12.1 Increasing storage in detention basins – hydraulic benefits

A Ridgidrain/Ridgistorm-XL drainage system installed within a drainage layer below the detention system base, can provide positive drainage of the system and assist with its draining.

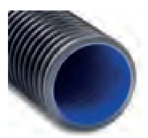
Polypipe is able to offer a wide range of thermoplastic pipe systems, including a comprehensive range of pipe diameters and fittings, allowing simple integration into the drainage system.



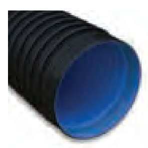
Where the attenuation storage capacity of the detention basin has effectively been increased through the provision of a positive drainage system below the basin invert, further attenuation storage capacity may be provided by oversizing the nominal perforated pipe which would typically be installed.

In particular where it may have a shallow longitudinal gradient towards the system outlet. Polypipe is able to offer a number of product ranges that can be used for this application:

Landcoil
PVCu single-walled flexible pipe system manufactured to BS 4962. Available in diameters from 60-200mm.



Ridgidrain
Thermoplastic structured walled surface water pipe system. Available as carrier, half perforated and fully perforated in diameters 100-900mm, 6m in length, lighter in weight than rigid materials.



Ridgistorm-XL
Thermoplastic structured walled surface water pipe system. Available as carrier, half perforated and fully perforated in diameters 750-3000mm, 6m in length, lighter in weight.

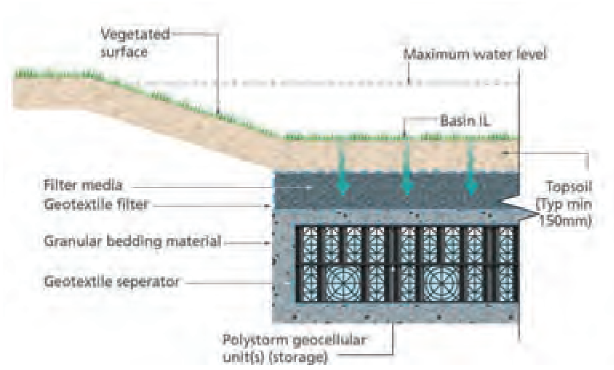
INTRODUCTION
3.1 BLUE-GREEN ROOFS
3.2 PODIUM DECKS
3.3 TREES
3.4 SPORTS PITCHES
3.5 CYCLE PATHS
3.6 PERMEABLE PAVEMENTS
3.7 BIORETENTION SYSTEMS
3.8 ATTENUATION STORAGE TANKS
3.9 INFILTRATION SYSTEMS
3.10 SWALES
3.11 FILTER DRAINS
3.12 DETENTION BASINS
3.13 PONDS AND WETLANDS
3.14 FILTER STRIPS

Amenity benefits

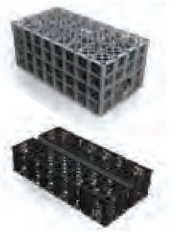
The use of Polypipe's range of pipe and geocellular systems can aid in the provision of additional amenity value of large area detention basins, in particular where the community utilisation of the space benefits from maintaining a drained vegetated area (i.e. sports pitch).

Consideration may also be given to increasing the potential attenuation storage provided below the basin invert, with the increase in attenuation storage achieved through substituting the pipe for a geocellular unit from our Polystorm product range.

The Polystorm and Permavoid systems have a significantly higher void ratio compared with granular material. It should be noted that a careful assessment of the expected groundwater levels would be required with this approach, to ensure that buoyancy of installations below the basin invert would not occur.



Polypipe Geocellular Products					
Code	Description	Length (mm)	Width (mm)	Depth (mm)	Storage per m
PSM1A	400mm Polystorm Unit	1000	500	400	0.19
PSM3	200mm Polystorm Unit	1000	500	210	0.105
PVPP85	85mm Permavoid Unit	708	354	85	0.021
PVPP150	150mm Permavoid Unit	708	354	150	0.038



Polystorm and Permavoid geocellular units
(Sections 2.4 and 2.5)
High porosity modular unit, installed in channels (acting as a conduit) within a drainage layer below the detention system base, providing positive drainage of the system. Flows are typically driven by hydraulic head.

Improved maintenance and inspection

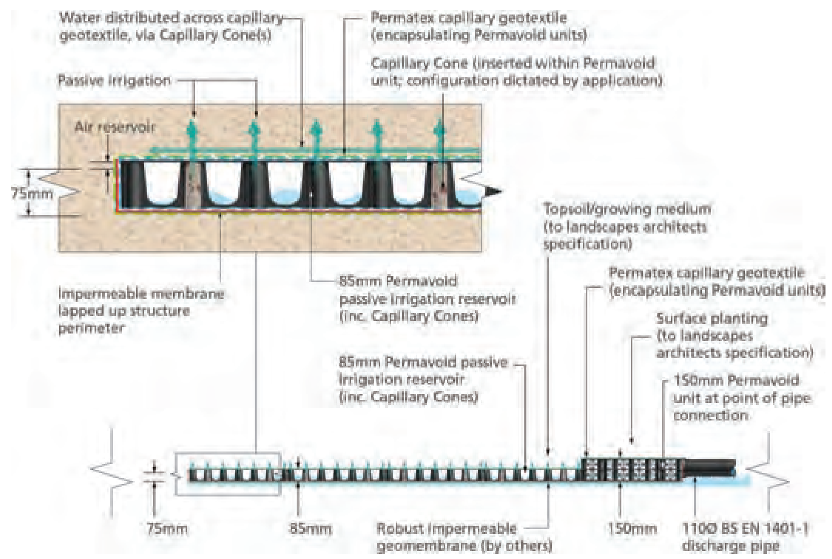
Installation of Polypipe's range of associated pre-fabricated chambers facilitate the inspection and maintenance of an underdrain system, particularly where they extend over a significant distance. Polypipe fabricated chambers may also be used to incorporate a range of pre-fitted flow control devices, allowing simple introduction into the drainage system.

RIDGISTORMSeparate Catchpit

RIDGISTORMCheck Vortex Flow Control

Passive irrigation

Where a proposed increase in the amenity value of a detention basin involves the incorporation of sports facilities (i.e. football pitch); Polypipe is able to supply a Permavoid geocellular system. Use of a Permavoid passive irrigation system beneath a grassed sports area, is able to serve the dual purpose of ensuring the pitch is positively drained, with a high strength load bearing system, while maintaining the soil moisture content via a reservoir of stored water. Irrigation is achieved through the use of an inert porous medium that draws water retained within the Permavoid unit and in conjunction with a hydrophilic geotextile, allowing the wicked stormwater to be distributed across a large surface area. The result is a zero energy irrigation system.



Polypipe Products		
Product	Description	Code
Polystorm Geocellular Unit	May be used to disperse water from point inlets within the pavement sub-base.	PSM1
Permavoid Geocellular Unit	Sub-base replacement: providing significantly higher storage capacity, compared with an equivalent depth of granular sub-base material.	PVPP85 PVPP150
Permavoid Rainwater Diffuser Unit	Used to disperse surface water from point inlets, where discharged within the sub-base.	PV09011
Permavoid Biomat	Incorporated within a Permavoid structure, typically restricted to the location of point inlets, to provide additional hydrocarbon treatment.	PV150BM
Permafoam	An open celled absorbent phenolic foam incorporated into Permavoid geocellular units for 'on demand' irrigation or check dams.	PVPP85PF PVPP150PF
Permachannel	Collection of surface water run-off from an impermeable pavement surface, includes elements that provide a high strength of initial water treatment.	PV03001
Permafilter	Proprietary geotextile designed to offer enhanced hydrocarbon pollution treatment, typically installed beneath the surface layer(s).	PV23002
Geomembrane	May be used to form check dams within the permeable pavement construction, limiting loss of attenuation storage, within developments containing steep gradients.	-
Geotextile	A non-woven, dimpled, needle - punched geotextile designed for hydrocarbon pollution treatment.	PV23008
Capillary Geotextile	A heavy-duty, non-woven, needle-punched geotextile made from a blend of modified polyester fibres. It is specially formulated to absorb water used to irrigate mineral substrates when used in conjunction with Permavoid units.	PV23007
Permavoid Capillary Cones	Enabling passive irrigation via capillary action, for use on roof gardens, Green roofs, sports pitches and arenas.	PVPP85CC2 PVPP85CC4

Treatment benefits

Where an underdrain system is installed within a granular material below the basin base, the effectiveness of the pipe and filter material in treating hydrocarbons can be increased, through the direct substitution of the pipe with:

Ridgitreat

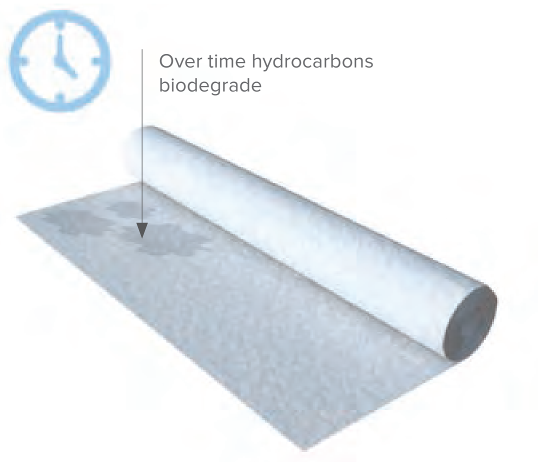
Permafilter geotextile wrapped perforated pipe system; designed to catch, filter and facilitate the break-down of hydrocarbons. Available in 100, 150, 225 and 300mm pipe diameters.

Where a geotextile filter material is used within the construction of a positive base drainage system, Polypipe is able to offer proprietary Permafilter geotextile, which is specifically designed to treat hydrocarbons within surface water flows. Permafilter is a dimpled non-woven needle punched geotextile, comprising a proprietary blend of hydrophilic and hydrophobic fibres. The proprietary blend of fibres is designed to retain hydrocarbons on the geotextile; in addition to maintaining a level of moisture that encourages biofilm formation and subsequent aerobic biodegradation of the retained hydrocarbons.

If a positive drainage system is incorporated into a detention basin construction, it should be noted that any water collected within a positively drained zone may not receive the same level of water treatment, compared with flows travelling along the whole vegetated basin system. Consideration should therefore be given to the form of the inlet(s), outlet and overflow location within the system and construction.

Permafilter Geotextile demonstrates retention of up to 6 litres of oil per 10m^2. The maximum discharge of effluent is typically 4.5ppm* during the first flush and during consecutive rain events only an average concentration of 1.5ppm.

*ppm = parts per million



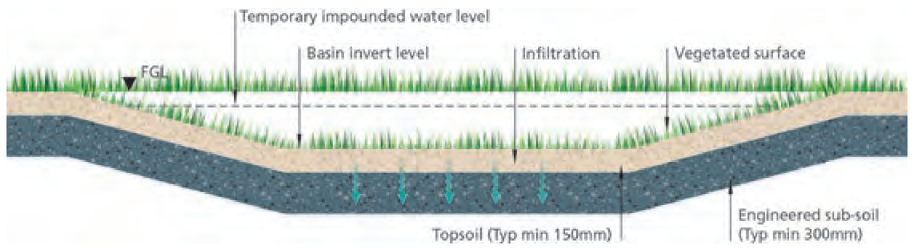
3.12.2 Typical construction

Where possible, when defining a detention basin profile, attention should be given to complementing the project's landscape architectural design. This is typically achieved through the avoidance of using uniform shapes to form the basin, or the strategic use of planting. Again, the profile of the depression sides can be varied to suit the landscape design.

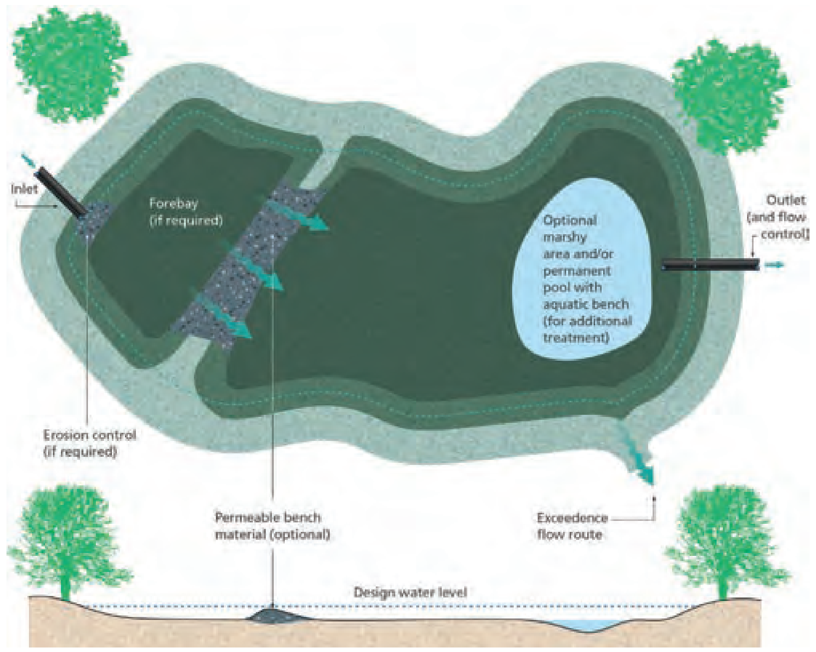
The form of the vegetated detention basin should be such that it minimises the risk of erosion, in addition to maximising water treatment opportunities; this is typically achieved with a detention basin that has:

- A length to width ratio of 3-5:1.
- Side slopes with at maximum 1 in 3 (33%) gradient.
- Nominal base gradient of 1 in 100 (1%) falling towards the system outlet.
- A maximum retained water depth of 2.0m.

Unless the system design includes specific landscaping or planting elements to prevent unauthorised access, side slope gradients and retained water depths would typically be restricted to those detailed above on safety grounds. Whether this is to protect the general public, or operatives undertaking future maintenance activities.



Where insufficient pre-treatment SuDS systems exist upstream of the detention basin (e.g. retrofitted basin within an existing below ground drainage system), consideration should be given to the construction of a forebay at the system inlet – providing a basic level of initial water treatment and facilitating future maintenance operations. Creation of a permanent marsh or pond at the outlet end of the system may also be considered, which would add an additional level of water treatment capability. A permanent pond may also offer opportunities to reduce the risk of deposited silts within the system being re-entrained, or detailing options for the outlet to increase its protection from becoming blocked with larger debris.



The form of the inlet(s), outlet and overflow (where required) construction, should therefore typically consider:

- The inclusion of elements at the inlet that dissipate the energy from inflowing water, while encouraging the formation of sheet flow across the width of the detention basin base; reducing the risk of erosion due to the formation of channelised flows
- Consideration may also be given to constraining low flows to specific areas of the basin, in order to facilitate multifunctional use
- Future maintenance access requirements
- Minimising, where possible, the number of point connections into a detention basin to a single inlet and outlet

Where the proposed amenity uses of the detention basin (i.e. sport fields), require the base of the basin to be drained – especially where infiltration through the detention base is not feasible – maximising its utilisation may therefore necessitate the installation of a drainage system under the vegetation surface of the base.

3.12.3 On-line system general arrangement

Vegetated on-line systems are typically constructed with the inlet and outlet connections positioned at the extreme ends of the basin, maximising the water retention times of flows generated by low intensity rainfall and therefore providing optimal water treatment opportunities.

The optimum level of water treatment efficiency is considered to be achieved when the basin is designed to manage flows from the critical water quality rainfall event (typically events up to the 1 in 1-year, 100% probability, rainfall event), so that:

- Flow velocity does not exceed 0.3 m/s
- Flow depth is restricted to a maximum 100mm
- Minimum retention time of 9 minutes is achieved

Where space allows, the contours of a basin base may be further developed to extend the flow path (and retention time across the system) of flows generated by the frequent rainfall events. This is typically achieved through effectively creating a vegetated channel(s) (i.e. swale) along the basin base.

Off-line system general arrangement

Off-line systems may effectively combine the inlet and outlet connections, with the detention basin gradient falling towards this connection.

Off-line detention basins are typically not utilised during low intensity rainfall events, but may be required to provide sufficient attenuation storage to reduce the risk of flooding (within the development) during high intensity rainfall, up to the 1 in 100-year (1% probability) events.

For more information please refer to:
The SuDS Manual (C753), Section 22: Detention Basins.

3.12.4 Hydraulic benefits

While the primary purpose of a detention basin system is to provide attenuation storage, vegetated systems may also provide the following hydraulic benefits:

Interception and infiltration; reducing the volume of surface water that may need to be discharged from the development, through:

- Infiltration into the underlying soils, when feasible (refer to 3.9)
- Attenuation within the soil matrix that supports the vegetated surface, and
- Evapotranspiration

However, the hydraulic design of a detention basin may also need to consider the system's water treatment efficiency (refer to 3.12.5), in addition to maintaining the system's utilisation if used to offer secondary amenity benefits. This may require the inclusion of a subsurface drainage system beneath the base of vegetated detention basins.

Attenuation storage capacity can be increased within the system by providing a thicker base drainage layer, or by introducing proprietary surface water storage systems within the layer, as a replacement to the granular material. Where there is insufficient space available within a development to install a detention basin with sufficient attenuation storage capacity, this option may still allow a detention basin to be used, while providing the attenuation storage required in a reduced footprint. However, careful consideration of the expected ground water levels would be required to prevent uplift of the construction below the detention basin base.

3.12.5 Water treatment

A significant reduction in the potential pollution impact of surface water run-off can be obtained through the attenuation of run-off generated by high frequency rainfall events, typically approximated by a 5mm rainfall depth.

On-line vegetated detention basins can offer opportunities to provide interception, through:

- Infiltration into the underlying soils, where technically feasible (refer to 3.11)
- Attenuation within the soil matrix that supports the surface planting/vegetation, and
- Evapotranspiration

Higher levels of water treatment can be achieved by ensuring low water flow velocities through the basin surface vegetation and the depth of flow does not significantly exceed the vegetation height. Optimum treatment efficiency is typically achieved when an approximate maximum water flow velocity of 0.3 m/s is maintained. This enables the following treatment mechanisms to remove:

- Coarse sediments, via filtration through the surface vegetation
- Fine sediment, via sedimentation; with low flow velocities and a minimum retention time within the swale, promoting the deposition of silts entrained within the surface water run-off
- Nutrients and dissolved metals, through biodegradation and plant uptake
- Chemical compounds, by photolysis and volatilisation

Where an underdrain is proposed for incorporation within the basin base, unless careful thought is given to its design, the system's overall water treatment efficiency could be significantly affected due to water flows effectively by-passing the vegetated surface. However, fine silt particles and other pollutants can still be removed through sedimentation and sorption within the vegetation growing medium and the underdrain granular bedding material.

When considering surface water run-off from high intensity events, the flows generated by these events would typically have significantly lower system retention times. Depending on the pollutant and sensitivity of the off-site receptor, the resultant higher levels of dilution under these conditions can reduce the potential severity of the pollutant's impact. However, high flow velocities can cause the re-entrainment of pollutants, if the subsequent flow's conditions generated are significantly higher than the optimum water treatment velocities, especially where the system design does not allow for exceedance. A SuDS treatment train that appropriately manages water flows within the system, is therefore able to minimise the risk of the treatment capability of other SuDS systems being overwhelmed, pollutants being re-entrained by the high flows or damage to the vegetation cover through erosion. Management of water flows through a drainage system can be enabled by the provision of attenuation storage, which detention basins are able to provide.

3.13 Ponds and Wetlands

Ponds and wetlands typically consist of a landscaped surface depression that features a permanent pool of water, with the system depth typically allowing the provision of temporary attenuation storage above the permanent pool.

The profile of the system base is typically landscaped to produce varying depths of permanent water and areas suitable for both submerged and emergent planting, both around the periphery and within the body of the system; including strategically placed 'islands'. The main differentiator between ponds and wetlands typically being the proportion of the system plan area given over to aquatic vegetation cover.

Ponds and wetlands can be used on most development types, with the profile of the system able to be adapted to suit the landscape design, including the incorporation of hard landscaping elements within high density urban areas. Where existing drainage system levels, space availability and ground conditions allow, ponds or wetlands may also form part of retro-fit schemes.

As part of a well-designed SuDS Management Train, ponds or wetlands can offer numerous benefits, both in the management of water quality and quantity, but also offer an opportunity to increase amenity value and biodiversity. It should be noted that within the context of this document, the use of the term wetlands refers to surface flow systems.

Indicative Treatment Efficiency

Pollutant	Reduction: Inlet to Outlet	
	Pond	Wetland
Dissolved Copper	≤ 40 %	≤ 30 %
Dissolved Zinc	≤ 30 %	≤ 50 %
Suspended Solids	≤ 60 %	≤ 60 %

DMRB Volume 4; HD/16, Table 8.1

In the event of a spillage, the maximum reduction of spillage risk considered achievable:

Optimum Risk Reduction Factor RF
0.5 (50%)

Indicative Treatment Efficiency

Pollutant	Mitigation Indices	
	Pond	Wetland
Total Suspended Solids	0.7	0.8
Dissolved Metals	0.7	0.8
Hydrocarbons	0.5	0.8

CIRIA C753; Table 26.3 – discharges to surface water

Multifunctional benefits of ponds and wetlands

SURFACE WATER MANAGEMENT
Site level flow control.

WATER QUALITY
Water treatment offered via lateral flow of water through the vegetation in the pond or wetland. Enhanced with the inclusion of upstream proprietary treatment systems.

PLACEMAKING
Ponds can be designed to easily fit within a development, providing aesthetically appealing features within an urban environment. In general the community valued SuDS ponds and felt that they added value to the area and to their homes.

HEALTH & WELLBEING
Ponds or Wetlands that are accessible or overlooked can increase mental wellbeing.

AMENITY
Permanently wet ponds can be used to store water for reuse, and offer excellent opportunities for the provision of wildlife habitats. Ponds can be part of public open space.

BIODIVERSITY
Ponds & Wetlands can include a variety of planting which can make a positive contribution to urban biodiversity.

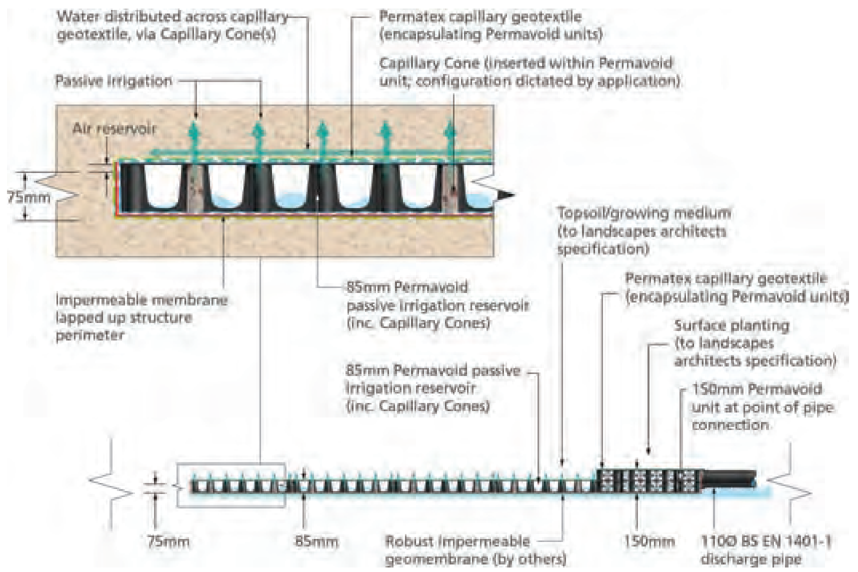
EVAPORATIVE COOLING
Ponds can provide cooling via return of moisture to the air through evaporation from the water surface. Can reduce local temperatures. Can also reflect sunlight.

ASSET CREATION
People have a strong emotional attachment to water, arising from its aesthetic qualities - tranquility, coolness and beauty.

3.13.1 Passive irrigation enhancement

Polypipe is able to offer a number of systems that may be installed to provide additional attenuation storage, or facilitate infiltration, to allow the management of the surface run-off volume generated by extreme rainfall events. In conjunction with the use of Polypipe pre-fabricated chambers, that offer the flexibility to incorporate a range of flow control devices, may be used to divert surface water flow to systems providing attenuation storage.

Use of a Permavoid passive irrigation system beneath the dry bench, typically specified around the perimeter of a pond or wetland system, is able to serve the dual purpose of ensuring the bench is positively drained to maintain access; while maintaining the soil moisture content via a reservoir of stored water to support vegetation planting. The irrigation is achieved through the use of an inert porous medium that draws water retained within the Permavoid unit and, in conjunction with a hydrophilic geotextile, allows the wicked stormwater to be distributed across a large surface area, thus providing a zero energy irrigation system.



Hydraulic and treatment benefits

Polypipe is able to offer a wide range of thermoplastic pipe systems, including a comprehensive range of pipe diameters and fittings, allowing simple integration into the drainage system.

Installation of Polypipe's range of associated fabricated chambers facilitate the inspection and maintenance of associated system connections. Polypipe fabricated chambers may also be used to incorporate a range of pre-fitted flow control devices, providing a simple method of achieving management of surface water flows.

When flow controls are used in conjunction with systems that provide attenuation storage, higher levels of water treatment – for a greater volume of surface water – could be achieved.

RIDGISTORMSeparate Catchpit

RIDGISTORMCheck Vortex Flow Control

The provision of attenuation storage within the drainage system, other than within the pond and wetland itself, which can be utilised during extreme rainfall events (typically rainfall generated by > 1 in 1-year (100% probability) event), allows the pond to be optimised to provide the maximum level of water treatment and amenity, which offers the following benefits:

- Minimises the risk of:
  - Erosion
  - Damage to vegetation
  - Design flow (treatment) routes being short circuited
  - Re-entrainment of pollutants
- Maximises the volume of water that is able to be treated prior to discharge from the site
- Enables ponds to be used, within constrained sites, where it may not otherwise be used due to the land required to include attenuation storage within the system

3.13.2 Typical construction

When defining the pond or wetland profile, in addition to ensuring adequate hydraulic performance, attention should be given to complementing the project's landscape architectural design wherever possible.

This is typically achieved through the avoidance of using uniform shapes to form the depression profile, or the strategic positioning of planting. The profile of the natural ground may be utilised to form the system depression, along with excavation of material, or the construction of new embankments.

Typically, a pond or wetland design may include the following elements:

Forebay

Where insufficient pre-treatment SuDS exist upstream of the detention basin, a forebay is typically constructed at the system inlet(s) to provide a basic level of initial water treatment. Forebays are designed to control silt and debris within a localised area, facilitating future maintenance activities but also limiting the risk of more frequent, onerous and expensive maintenance activities (i.e. desilting) being required within the main body of the system.

Aquatic bench(es)

Areas of shallow water depth that are designed to support aquatic planting; typically larger in area for wetlands to allow denser planting/vegetation.

Permanent treatment pool(s)

Permanent depth of water that acts as the main treatment zone, which in larger ponds, may be sub-divided into a series of micro pools. The upper water level of the permanent pool typically coincides with the invert of the system outlet, unless infiltration around the pool periphery forms part of the system design.

Temporary attenuation storage volume

Volume of water, above the permanent pool, that is temporarily retained within the system during rainfall events.

Connection of other drainage elements (i.e. pipe conduit) into the pond or wetland system requires careful detailing, to ensure:

- Low energy flows into the system; minimising the risk of erosion or vegetation damage
- A sufficient retention time of inflows into the system; to achieve target levels of water treatment
- Entrained sediment is managed prior to flow entering the main body of the system; facilitating future maintenance
- The risk of inflows entering the pond or wetland short circuiting the design flow path is minimised; typically a risk with water flows generated by rainfall events greater than those used to design the water quality treatment efficiency of the system (typically greater than 1 in 1-year, 100% probability, event)

The above is facilitated by limiting the number of connections into the system, if possible to a single inlet and outlet. Design of an overflow adjacent to the inlet(s), to manage exceedance flows, would minimise the risk of the inflows short circuiting the system, which would damage planting or cause erosion as a consequence.

The form of the pond or wetland basin should therefore be such that it minimises the health and safety risks to maintenance operatives or the general public, in addition to minimising the risk of damage to planting or erosion, while maximising water treatment opportunities. This is typically achieved with a pond or wetland basin that has the following physical characteristics.

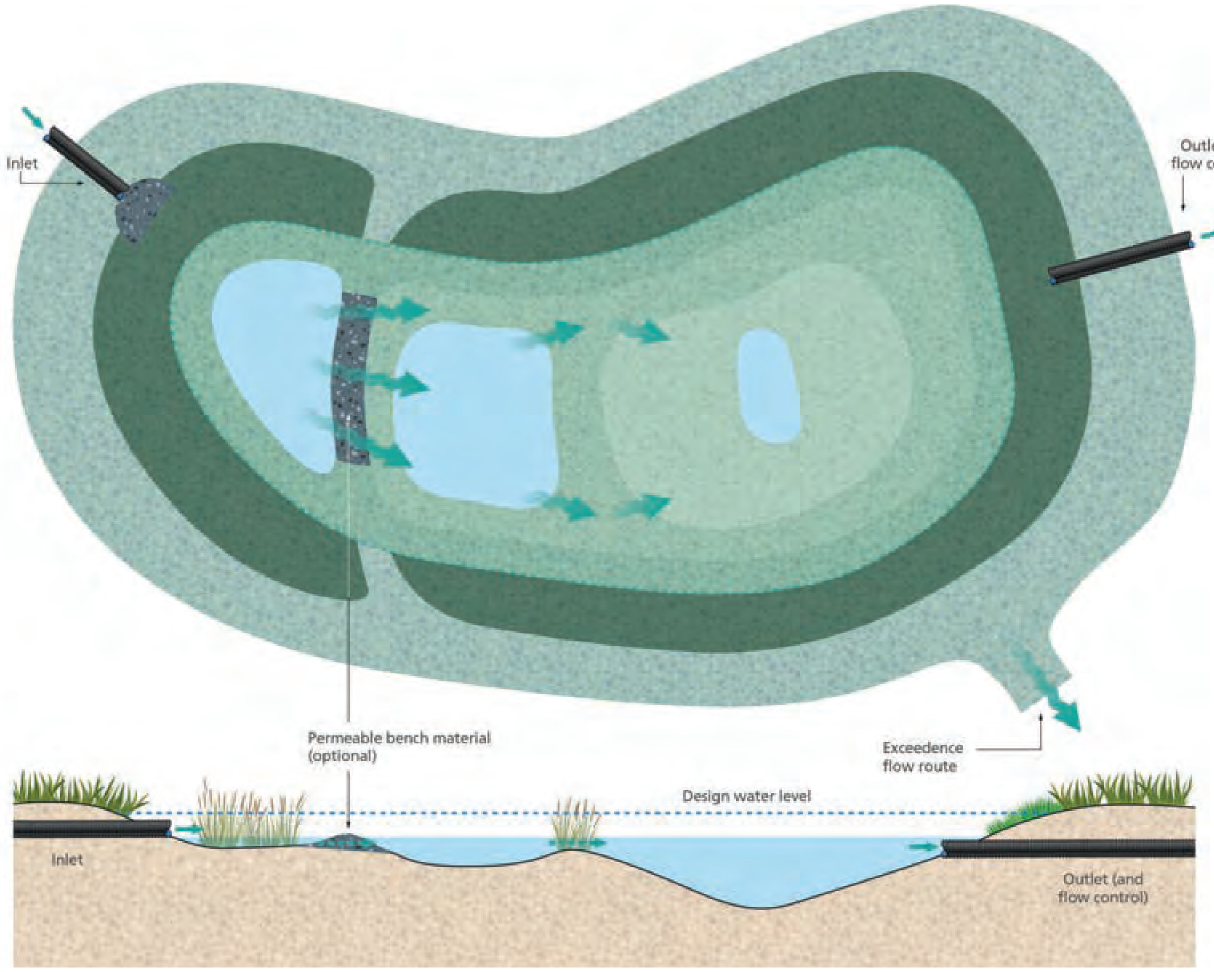
- Safety bench; typically, 3.5m-wide dry bench around system perimeter, with a shallow gradient less than 1 in 15 (7%)
- Pond margin with a maximum 1 in 3 (33%) to 1 in 4 (25%) gradient; this zone may include a series of vegetation benching, establishing planting at different water depths, allowing a range of plant species. The width of the vegetated benches dictated by the pond design
- A length to width ratio of 3:1 to 5:1
- Side slopes with at maximum 1 in 3 (33%) gradient
- Nominal base gradient of 1 in 100 (1%), falling towards the system outlet
- A minimum open water depth of 1.2m
- Maximum retained water depth within permanent pool of 2.0m
- Inlet flow velocity into system main body restricted to 0.3-0.5 m/s
- Maximum water attenuation storage depth (above permanent water depth) of 0.5m; unless risk mitigation measures considered during the system design
- Nominal 300mm freeboard, above the water level associated with the design rainfall event

In larger systems, the design may include a series of micro pools with water depths between 0.6 and 1.0m, which reduce the risk of excessive biological activity (algae blooms) during the summer months. Designing the system with the greater water depths at the outlet reduces the risk of captured silts being re-entrained and may also result in lower temperature discharges from the system.

Unless the system design includes specific landscaping or planting elements to prevent unauthorised access, side slope gradients and retained water depths would typically be restricted to those detailed above on safety grounds. Whether this is to protect the general public, or operatives undertaking future maintenance activities.

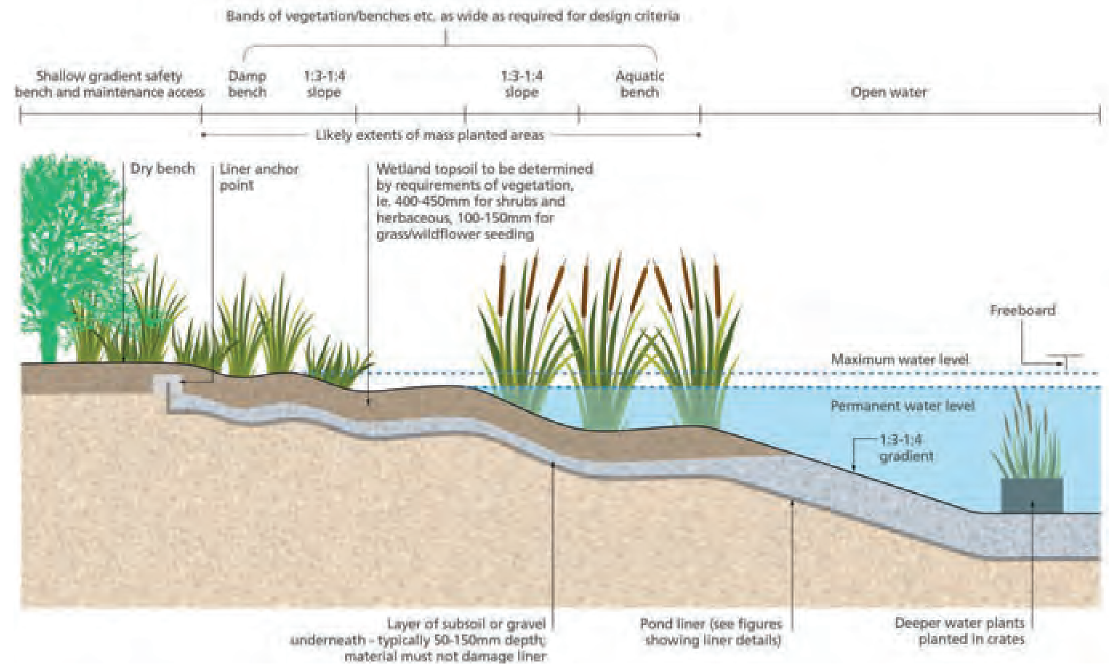
The treatment efficiency of a pond and wetland system is typically dictated by the length of time that a volume of water which flows into the system is retained within the system, allowing sedimentation and biological degradation or uptake to take place. The volume of the permanent pool, compared with the inflow volume, may be used to determine the system's probable treatment efficiency. This is particularly pertinent where permanent pool volumes greater than twice the mean annual rainfall (Qbar; circa 1 in 2.3-year return period, 43% probability), or 10-15mm rainfall depth over the catchment area draining to the system, offer negligible increases in treatment efficiency.

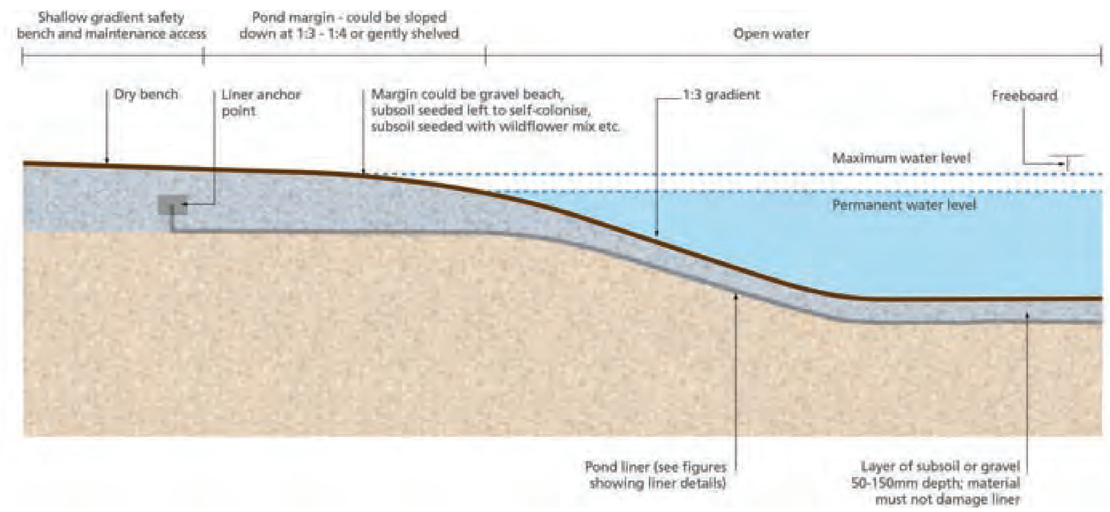
Where lower levels of treatment efficiency is required (i.e. the pond/wetland forms the downstream element of a SuDS Treatment Train), smaller permanent water volumes may be considered.



Due consideration should also be given to the suitability of the ground conditions for the impoundment of a permanent water body. The permeability of the soils beneath the system should be assessed to ensure that water levels within the system can be maintained. Where the soils are found to be insufficiently impermeable, the installation of an impermeable geomembrane or lining of impermeable material (i.e. clay) should be used. This approach would also apply to developments within contaminated sites, where the drainage system is required to be completely sealed, to prevent the mobilisation of contaminants.

The position of trees and shrubs adjacent to the pond should also be taken into consideration; situated so that they can offer sufficient shade to reduce the risk of thermal heating of the permanent water, while far enough away to prevent them overhanging the system.





3.13.3 Hydraulic benefits

Unless the pond or wetland system has been designed to allow infiltration around the perimeter of the permanent water pool, ponds and wetlands would typically offer minimal interception.

Provided the system is designed with sufficient storage capacity above the permanent water level, in conjunction with a flow control at the system outlet, ponds or wetlands are able to provide attenuation storage capacity. Although they would not provide a significant contribution to the control of a development's total discharged water volume.

3.13.4 Water treatment

Pond and wetland systems are able to offer effective water pollution management, with the system's dimensional flexibility allowing them to be used on a wide range of development types.

They are particularly effective when used at the end of a SuDS Treatment Train as a final high level (enhanced) water treatment system – in particular, where previous elements within the drainage system provide initial levels of water treatment.

It should be noted that ponds function most efficiently when inflows into the system traverse the system as a single volume 'block' or 'plug', which displaces an equivalent volume through the system outlet. Each volume 'plug' being retained within the system for a sufficient period of time to achieve nominal levels of water treatment. Ponds and wetlands should be designed to prevent the section of the system above the permanent water level being flooded for significant periods of time; to minimise the risk of future maintenance problems.

A wide range of planting types and densities can be accommodated within the system, enabling plant species that are efficient in taking up key pollutants to be used. Water treatment is achieved as surface water flows through the vegetation and percolates through the growing media. This enables the following treatment mechanisms:

- Sediment removal, via filtration through the surface vegetation and filter media
- Nutrient and dissolved metal removal, through biodegradation and plant uptake
- Chemical compounds, by photolysis and volatilisation
- Sorption with the filter media particles

When considering surface water run-off from extreme events, which can have a lower immediate pollution impact due to higher levels of dilution, it should be noted that the total volume of pollutant is not reduced. Careful consideration should be given to the design of the system overflow or exceedance flow routes; in order to minimise the risk of the normal system flow path being short circuited, damage to the vegetation planting, erosion or re-entrainment of captured silts.

3.14 Filter Strips

Made from dense vegetation – typically grass – filter strips are uniformly sloped sections used to pre-treat low velocity surface water run-off from linear lengths of hard surfacing.

Indicative Treatment Efficiency	
Pollutant	**Reduction: Inlet to Outlet**
Dissolved Copper	0%
Dissolved Zinc	45%
Suspended Solids (TSS)	60%

Data source – DMRB; HD 33/16

The lengths of vegetation capture sediments and soluble pollutants from roads, car parks and pavements allowing the remaining water to infiltrate downward into the soil. Filter strips can also be effective as a combined SuDS solution with a filter drain and/or silt trap.

Multifunctional benefits of filter strips

SURFACE WATER MANAGEMENT
Interception at source.

WATER QUALITY
Water treatment offered via lateral flow of water through the vegetation in the filter strip. Enhanced with the inclusion of treatment geotextiles where infiltration is allowed.

BIODIVERSITY
Filter Strips can include a variety of planting which can make a positive contribution to urban biodiversity.

3.14.1 Polypipe GU solution

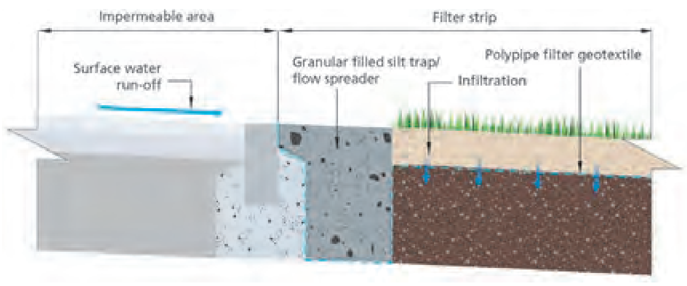
Filter strips alone can make a valuable contribution to Green Urbanisation creating conveyance and storage at source.

Conventional infiltrating filter strip designs can be enhanced by the use of Polypipe geotextiles.

Hydrocarbon concentrations within surface water infiltrating through Polypipe Permafilter geotextile is limited to a maximum 5 parts per million (ppm) [5mg/l].**

It should be further noted that Permafilter encourages the formation of a biofilm, that actively biodegrades retained hydrocarbons.

[**Based on an oil load of 0.6 l/m^2 (600ml/m^2)]

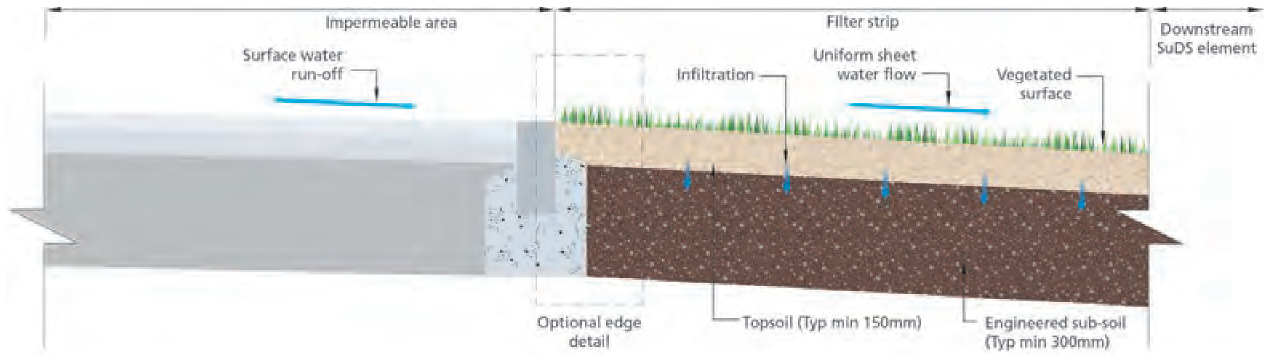


Optional granular filled silt trap and flow spreader trench (SuDS manual (C753) Section 15, Filter Strips, Figure 15.2)

For more information please refer to:
The SuDS Manual (C753), Section 15: Filter Strips.

3.14.2 Conventional SuDS

Filter strips are typically positioned as the initial drainage system Treatment Train element, along the boundary of a linear impermeable area; pre-treating surface water run-off prior to discharge into receiving SuDS elements.



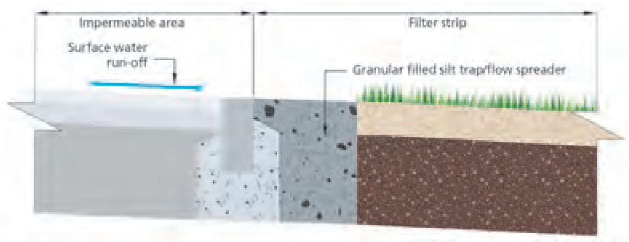
Filter strip schematic

Impermeable areas should have a gradual gradient towards the filter strip, with careful consideration given to the detailing of the pavement edge, to ensure uniform sheet flow onto and across the filter strip. A flow spreader may be installed at the interface between the impermeable area and the filter strip (i.e. granular filled trench), to encourage the formation of sheet flow along the whole filter strip. Ensuring the highest level of water treatment efficiency possible, in addition to reducing the risk of erosion due to the formation of channelised flows.

To optimise surface water flow velocity, for water treatment and minimising the risk of erosion, the gradient of the filter strip should typically be restricted to 2-5%. Where these gradients cannot be maintained due to site constraints, flow spreaders can be installed at intermediate points along the filter strip to maintain sheet surface flows.

Where space permits, the optimum width of the filter strip would typically be dictated by the target level of water treatment. Significant treatment benefits have been shown to occur with filter strip widths of approximately 2.5-3.0m, where the filter strip slope is < 1%, and at approximately 5.0m at steeper slopes.

Where the risk of groundwater pollution from infiltration through the filter strip has been determined to be significant, the installation of an impermeable liner (geomembrane) beneath the filter strip may be considered – typically installed 0.5m below the finished ground level.



Optional granular filled silt trap and flow spreader trench

Key considerations when assessing the use of a filter strip, are the risk of activities occurring at the proposed strip location that may impact its function (i.e. car parking), or proposed adjacent landscape planting inhibiting the growth of the surface vegetation (i.e. creation of excessive shade).

For more information please refer to:
The SuDS Manual (C753), Section 15: Filter Strips.

3.14.3 Hydraulic benefits

Filter strips may be designed to encourage infiltration into the underlying soils through the use of shallow gradients.

While significant infiltration of surface water would not normally be considered possible for this type of SuDS element, filter strips can potentially make a significant contribution to interception storage.

Design water flow velocities should typically be restricted below 1.5m/s to prevent erosion, however, it should be noted that lower velocities would be required to achieve efficient levels of water treatment.

Additional water storage can be created within the filler media by substitution of some of the material in the granular filled silt trap/ flow spreader with Ridgidrain or Polystorm - See section 3.11 'Filter drains' (page 212).

3.14.4 Water treatment

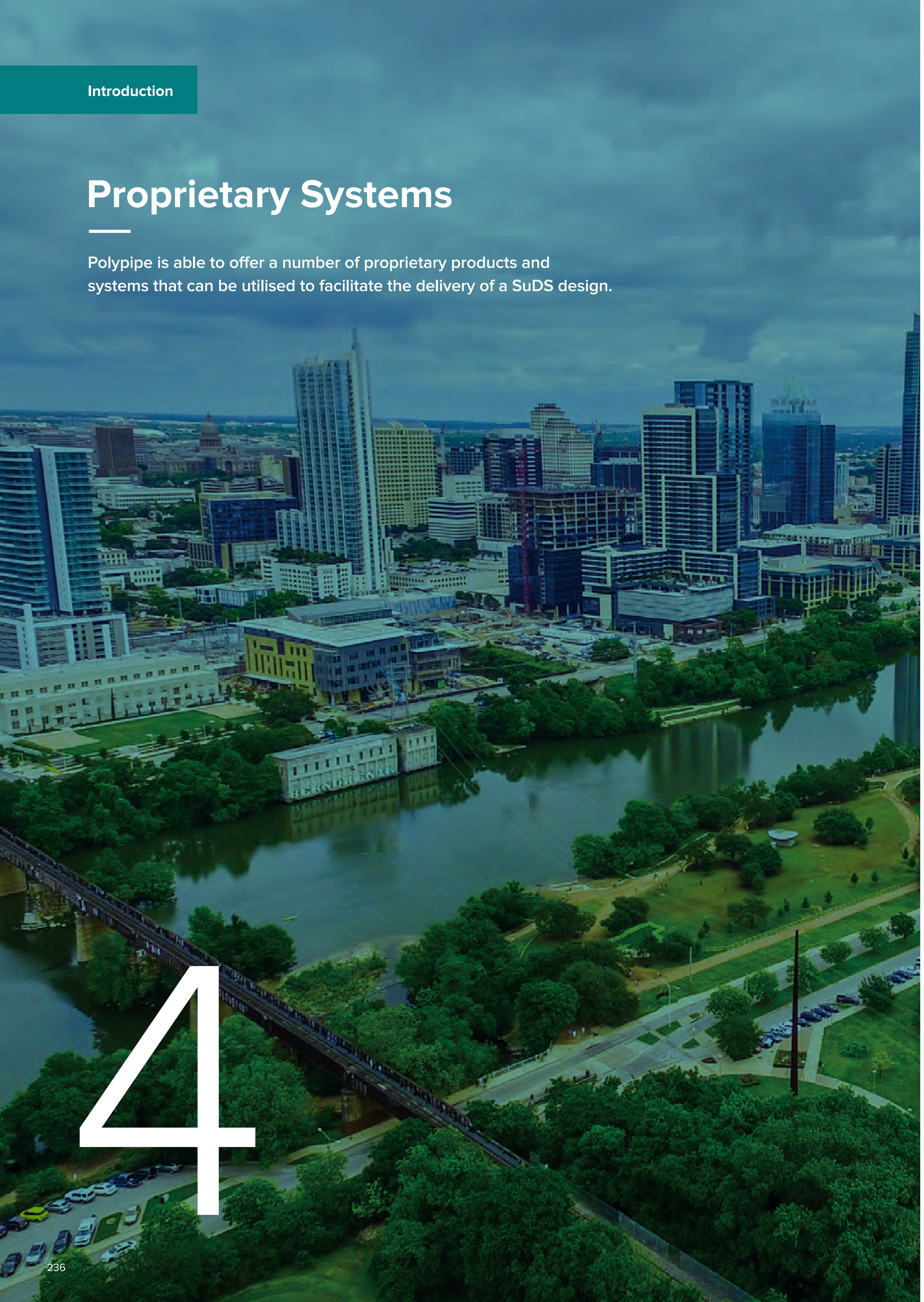
Filter strips are typically used to provide pre-treatment of surface water flows from impermeable surface areas, prior to discharge into SuDS 'collector' elements.

The reduction of flow velocities as water passes through the surface vegetation, encourages silt deposition across the filter strip; which is then trapped by the vegetation. Where surface water is allowed to infiltrate within the surface and sub-surface soils, further treatment may be achieved through biochemical processes – the biochemical process driven by the type of planting used and the active micro-organisms present within the engineered soils.

Water treatment has been shown to be effective for typical filter strip widths, with the below associated slopes:

Slopes <1%	0
Slopes >1%	5.0m

This of course assumes that the flow depths are at least lower than the height of the surface vegetation, are at peak flow velocities less than 0.3m/s and have a residence time across the filter strip of at least 9 minutes.



Introduction

Proprietary Systems

Polypipe is able to offer a number of proprietary products and systems that can be utilised to facilitate the delivery of a SuDS design.

4

This section gives an outline brief of each of the proprietary products currently offered by Polypipe Civils, in addition to providing typical areas of application and the specific water management benefits offered. Further information on the products specification and application guidance is available from Polypipe, via our website www.polypipe.com. Alternatively, Polypipe has internal and external technical teams who are available to discuss potential applications within the context of the proposed development in more detail.

As with any SuDS system, proprietary systems may require routine maintenance to ensure continued performance. Maintenance of the above products may require specific activities to be undertaken that involve work below ground or the use of specialist equipment (i.e. suction equipment to remove silt).

However, these activities may be familiar to a number of site owners or operators and could be undertaken as part of their normal maintenance activities. Therefore, when used to manage the surface water run-off, proprietary systems may offer the most cost effective solution for these operators/owners.

It should be noted that unless a proprietary product forms part of a system, multiple components would typically need to be combined in order to enable water quantity and quality to be managed, while maximising the opportunity for the Designer to increase amenity and biodiversity within the overall development.

These products have been designed to deliver a number of benefits that may be used to either complement surface landscaped features, or offer hydraulic and water quality controls where the constraints of a site preclude the use of other systems.

Section 4 - Contents

Introduction

The importance of treatment

Water treatment is particularly important for SuDS systems that store rainwater for reuse or that discharge rainwater into water courses. At ground level in particular, rainwater can be polluted from fine or course sediment from road surface wear, vehicle tyre and brake fallout, vehicle exhaust matter, oils and hydraulic fluids and particles from aerosols and gases that are carried from the atmosphere by precipitation and deposited as surface water contaminants.

In fact, there are many pollutants to consider. Solids, such as silt, sediment, litter and vegetation. Metals, typically found in road dust. And Hydrocarbons, organic salts and herbicides. They're all present within surface water run-off from our road surfaces – and all cause significant, detrimental damage to receiving waters.[1]

We have treatment-enhancing systems to help capture, treat and store rainwater at source before it reaches important waterways. Specifically, most pollution run-off is attached to sediment and so our SuDS systems are designed to reduce or remove sediment. They'll help reduce flow velocities to a rate that allows sediment particles to fall out of suspension, for example. However, it's important that treatment SuDS perform at their optimum level, so our systems are designed to manage high levels of debris, but have built-in inspection facilities for ease of access to facilitate any periodic sediment removal.

1. Guidelines for the environmental management of highways; institution of Highways & Transportation; Feb 2001

Proprietary Systems

The proprietary products and systems that Polypipe currently offers may be generically classified by its function(s), summarised in the table below.

	Polypipe Product	Surface water run-off collection	Systems Interface	Below surface treatment system	Hydraulic control
1	**Permatreat and Permachannel** Surface run-off collection and treatment channel	•		•	
2	**Ridgitreat** Used to enhance linear collection systems (i.e. filter strips; refer to section 3.14)	•		•	
3	**Outfall Headwall** Preformed headwall unit		•		
4	**RIDGISTORMSeparate**				
a	**Catchpits** Silt trap and removable outlet filter			•	
b	**Filter Chambers** Silt trap and removable outlet filter			•	
c	**Silt Traps** Small diameter silt trap				
5	**RIDGISTORMSeparate-X4** Stormwater Treatment System			•	
6	**RIDGISTORMCheck**				
a	**Orifice Plate Flow Control** Chamber incorporating a pre-installed orifice plate				•
b	**Vortex Flow Control** Chamber incorporating a pre-installed vortex flow control unit				•
7	**Permavoid**				
a	**Permavoid Rainwater Diffuser Unit** Unit to dissipate surface water point inlet into permeable pavement sub-base		•		
b	**Permaceptor** Small capacity silt and oil interceptor			•	
c	**Permavoid Biomat** Geocellular treatment unit		•	•	
d	**Permafilter Geotextile** Specifically designed for hydrocarbon pollution treatment		•		
8	**Permavoid Passive Irrigation System** System components combined to offer passive irrigation	•			•
a	**Permavoid² 85 Irrigation** Six pre-connected units designed to provide attenuation and irrigation for shallow non-loaded applications	•			
b	**Permafoam Unit** Open-celled, phenolic foam incorporated into a high-strength Permavoid geocellular unit	•			•
c	**Permatex Capillary Geotextile** Heavy-duty, non-woven, needle punched geotextile, specifically formulated to absorb water and distribute it across the geotextile	•	•		

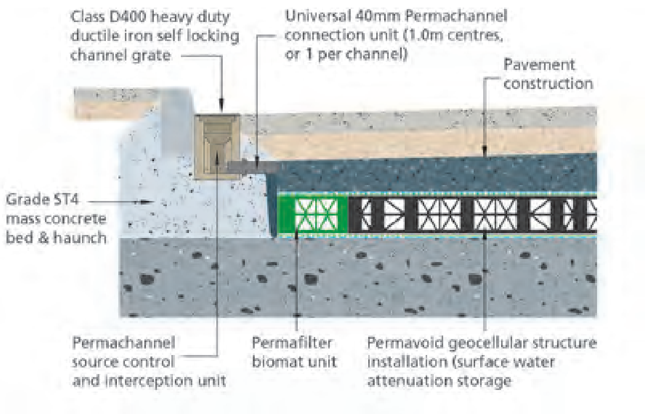
4.1 Permatreat and Permachannel

Permatreat and Permachannel are linear treatment channels that are able to offer water pollution management benefits at source.

Functioning as combined run-off collection, gravity silt and oil interceptor and treatment systems. Individual units are interconnected to provide the system length(s) required. Channel length is dependent on the contributing area that requires treating.

Permatreat and Permachannel are designed to be laid within a pavement surface at a zero or near zero gradient, to limit the linear flow velocities that may be generated along the channel, encouraging the deposition of silt within each channel unit. Water is discharged from the system, via an internal weir and baffle arrangement to separate oils, through an outlet positioned in the side of the channel. Offering effective control of the effluent and silt which is discharged from the system into the downstream drainage system.

Typically used with macro permeable pavements, where the multiple channel outlets are able to be simply integrated into the pavement granular sub-base layer or geocellular sub-base replacement system. This connection is facilitated through the use of Permavoid Biomat units which are able to provide an additional level of cleansing of the oils before water discharges into the storage tank.



Illustrative Permachannel typical installation

Permatreat

Available with two C250 grating options (Standard and Easy Access), Permatreat is a versatile, linear treatment system that can provide source control and pollution treatment in a wide variety of locations and applications. The Permatreat channel functions as a combined run-off collection system, whilst intercepting silt and oil from surface water run-off.

Permachannel

Available with a D400 grating, Permachannel offers the same benefits as Permatreat, but can be utilised in applications where heavier load bearing capabilities are required.

Permachannel
(Image for illustration purposes only)

Dimensions	Permachannel	Permatreat
Length [mm]	1000	1000
Width [mm]	150	139
Depth [mm]	210	201
Effective catchment area (per unit) [m²]	30.0	30.0

Hydraulic Benefits

As the units are able to be installed at very shallow or level gradients, the flow velocity generated at the system discharge point(s) is minimised.

Water Treatment Benefits

The Permatreat and Permachannel units are able to provide an effective level of water treatment that may be considered to be equivalent to a Class I separator, under assumed normal operating conditions.

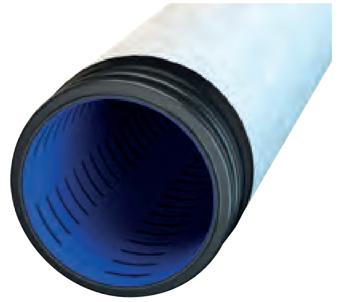
BS EN 858-1:2002, defines the performance requirement of a Class 1 separator as being able to offer:

- Discharge oil concentration < 5 mg/litre
- During surface water flows generated by an equivalent rainfall intensity of 6.5mm/hour

Permatreat
(Image for illustration purposes only)

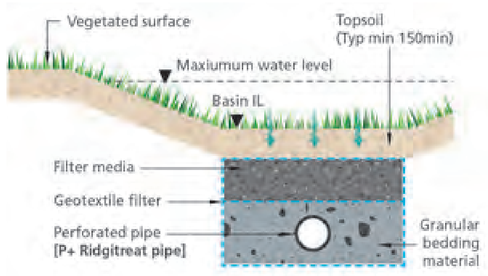
4.2 Ridgitreat

Ridgitreat is a perforated surface water treatment pipe, offering enhanced silt and hydrocarbon pollution management benefits.

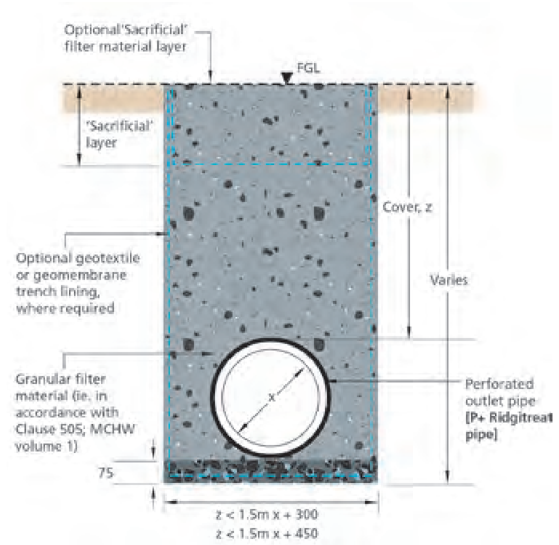


Designed to function within drainage systems that require a positive drainage element. Use of Ridgitreat, as opposed to a simple perforated pipe, can increase the overall effectiveness of the system in managing silt and hydrocarbon pollution.

Typically used at the invert of long linear or wide area drainage systems, to provide positive drainage of granular material elements within the system structure (i.e. filter strip and non-infiltrating permeable pavement; section 3.14 & 3.6 respectively).



a) Swale or detention basin at very shallow gradient



b) Infiltration drain

Ridgitreat is a perforated pipe system, pre-wrapped in a proprietary semi-permeable geotextile (Permafilter); designed to catch, filter and facilitate the breakdown of hydrocarbons. Compatible with Polypipe's Ridgidrain surface water drainage system, Ridgitreat is able to use the comprehensive range of Ridgidrain fittings available, to be able to form a drainage pipe network that can be simply integrated into the drainage system.

Ridgitreat	
Nominal pipe diameter [mm]	100, 150, 225 & 300
Length [m]	6

Hydraulic Benefits

Facilitates drainage of SuDS solutions; which are typically unable to infiltrate surface water into the underlying soils and/or are installed within a development at near zero gradients.

Water Treatment Benefits

The Permafilter geotextile, which encapsulates the Ridgitreat pipe, is specifically designed to treat hydrocarbons within surface water flows. Permafilter is a dimpled non-woven needle punched geotextile, comprising a proprietary blend of hydrophilic and hydrophobic fibres. The proprietary blend of fibres is designed to retain hydrocarbons on the geotextile; in addition to maintaining a level of moisture that encourages biofilm formation, and subsequent aerobic biodegradation of the retained hydrocarbons.

4.3 Outfall Headwall

Polypipe outfall headwalls are a high quality durable polymer headwall. Designed to allow simple placement and integration into the drainage system, especially within restricted access locations.

The headwall unit essentially functions as permanent formwork, which is infilled with either concrete or granular material, once installed in position.

The headwall units are available with a range of interchangeable collars that facilitate the connection of pipes of various diameters. A full range of integrated ancillaries are available; which includes handrails, flow controls (i.e. flap valves) and screens to prevent unauthorised access.

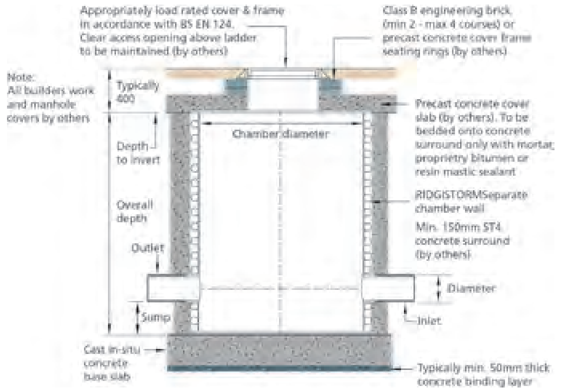
Unit characteristic			
Unit Ref		HW300	HW450
Nominal pipe diameter [mm]		100, 150, 225 & 300	150, 225, 300, 375 & 450
Overall dimensions	Height [m]	1.150	1.625
	Width [m]	1.147	1.700
	Depth [m]	1.150	1.400

4.4 RIDGISTORMSeparate

Polypipe is able to offer a range of pre-fabricated chambers which can be manufactured with a number of features that offer surface water pollution management options.

Polypipe utilises our range of thermoplastic structured walled pipe systems to form the chamber wall, typical diameters are summarised below.

RIDGISTORMSeparate diameters	
Nominal chamber diameter [mm] available as standard	750, 900, 1050, 1200, 1500, 1800, 2100, 2400, 2700 & 3000



Idealised RIDGISTORMSeparate Catchpit and Filter chamber typical installation detail

Ridgistorm-XL Component Chambers units are fabricated with the appropriate connecting pipe work to allow simple integration within the proposed drainage scheme. The units can also be supplied with a full range of ancillary items including, step rungs, ladders and lifting points. Please refer to the 'Four Step Guide to Ridgistorm-XL Pre-Fabricated Component Chambers' guide for further details of the numerous options available with this system.

4.4.1 RIDGISTORMSeparate Catchpits

Pre-fabricated units that may be used within surface water drainage systems to provide silt and debris separation and retention.

Idealised typical installation detail is given above.

4.4.2 RIDGISTORMSeparate Filter Chambers

Pre-fabricated units that incorporate both a sump and removable filter unit on the chamber outlet.

When used within surface water drainage systems, the unit is able to capture and retain silt and debris. The filter unit is easily removable for maintenance purposes.

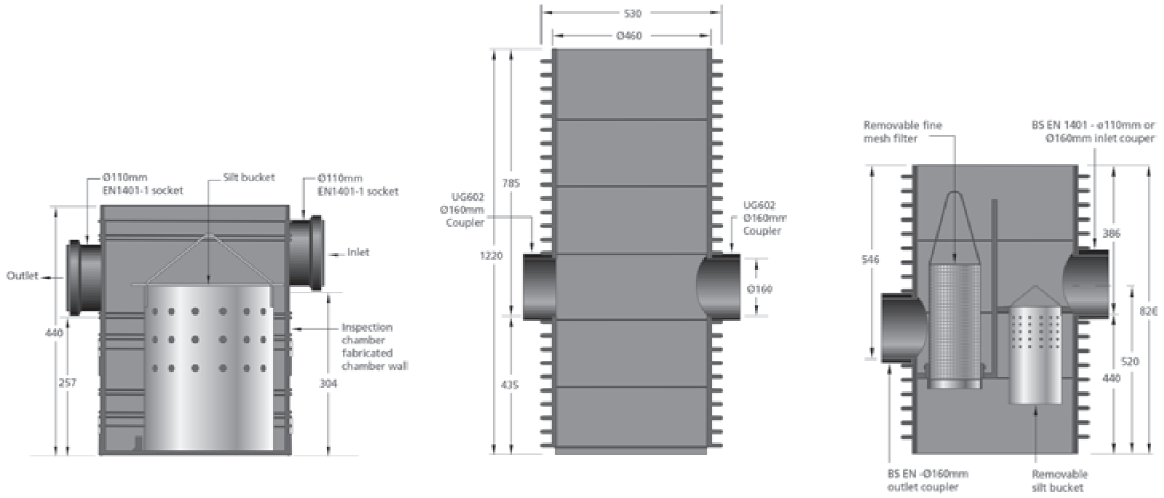
4.4.3 RIDGISTORMSeparate Silt Traps

Pre-fabricated units that may be used within surface water drainage systems to provide silt and debris separation and retention.

The Silt Trap units are designed to function as a surface water pollution control, immediately downstream of the surface water run-off collection system. Due to the limited connecting pipe diameter and sump depth, these units are typically used within systems draining small impermeable areas, usually associated with domestic residential dwellings.

Polypipe is able to utilise our range of thermoplastic inspection chambers to form the unit; the unit characteristics are summarised in the table below.

Silt Traps			
Unit Ref	Mini Silt Trap	Basic Silt Trap	Advance Silt Trap
Nominal chamber diameter [mm]	320	460	460
Inlet / Outlet pipe diameter [mm] [Supplied with BS EN 1401-1 socket]	110	160	160
Nominal sump depth [mm]	250	420	280
Additional silt control feature	Removable silt bucket	N/A	Removable silt bucket & fine mesh filter
Effective treatment capacity [l/s]	N/A	N/A	15 l/s



1) Mini silt trap **2) Basic silt trap** **3) Advanced silt trap**

Silt Traps typical section

Water Treatment Benefits

The RIDGISTORMSeparate Fabricated Chambers offer surface water pollution management options to control silt and debris entrained within the discharge from surface water collection systems, prior to its entry into the downstream drainage system.

The level of water treatment that may be expected from these units will vary according to the unit type. With the advanced silt trap offering an additional level of protection, due to surface water having to pass through a silt bucket and then flow up through a fine mesh (500μm) filter.

It should be noted that at flow rates greater than 15.0 l/s will bypass the filter elements within the advanced silt trap.

4.5 RIDGISTORMSeparate-X4 Stormwater Treatment System

RIDGISTORMSeparate-X4 offers advanced 4-stage filtration of surface water run-off, providing high levels of solid and dissolved phase contaminant removal, including hydrocarbons and heavy metals.

The RIDGISTORMSeparate-X4 stormwater treatment system utilises a number of processes to provide consistent levels of protection for the downstream elements of the drainage system and local environment. These processes occur in consecutive sections of the device, which may be generically defined as:

Dynamic Separator

1. An angled inlet, within the base section, induces a radial flow which promotes sedimentation of particular pollutants.

Filter Elements

2. As water flows up through the saturated filter elements, particulate matter is removed at 100% efficiency to 50 microns and, at lesser efficiencies, down to 1 micron.

3. Dissolved chemical pollutants are removed through adsorption, absorption and precipitation mechanisms.

Oil Retention

4. Water is discharged via an oil trap assembly that is designed to retain free phase oils; in particular in the event of a spill. As standard, the device is supplied pre-installed within a fabricated chamber, ready to install on-site. However, Polypipe is able to offer the RIDGISTORMSeparate-X4 as a stand-alone unit if required.

The device incorporates an overflow which by-passes the filter cartridge elements during peak storm conditions.

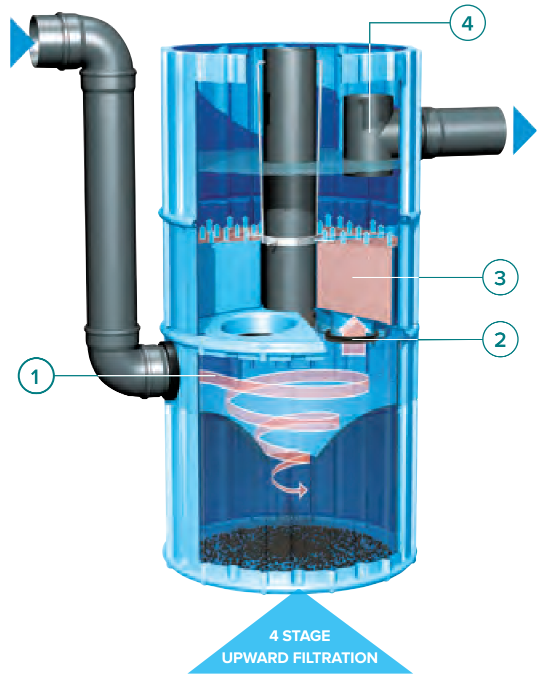
A number of device variations are available, the distinction between units being the filter element substrate, the design of which has been modified to suit the range of pollutants commonly encountered from specific hard standing areas.

Device characteristics are summarised in the table on the right.

Maintenance

Filter element cartridges typically require replacement after 2 years (based on a typical installation treating run-off from a heavily trafficked area); this filter replacement would usually occur when the flow efficiency reduces to 2.5 l/s.

We recommend that the unit is inspected every 6 months to measure sediment accumulation. However, more frequent inspections (i.e. after several heavy rainstorm events) may be undertaken to check the pollution load contained within the surface water run-off drained to the system is at expected levels. The maintenance schedule should then be revised accordingly.

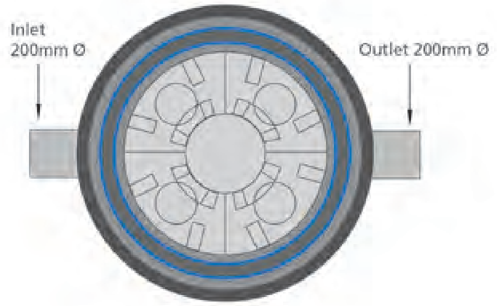


Device characteristics			
Device Application	Heavy Traffic	Traffic	Roof
Height [mm] stand-alone unit dimensions stated	1955	1955	1955
Diameter [mm] stand-alone unit dimensions stated	980	980	980
Weight [Kg] stand-alone unit weight stated	338	258	258
Recommended catchment area [m^2]	500	750	1000
Connecting pipe diameters [mm]	200	200	200
Inlet / Outlet invert level difference [mm]	1000	1000	1000
Effective treatment capacity [l/s] [1])	12.0	12.0	12.0

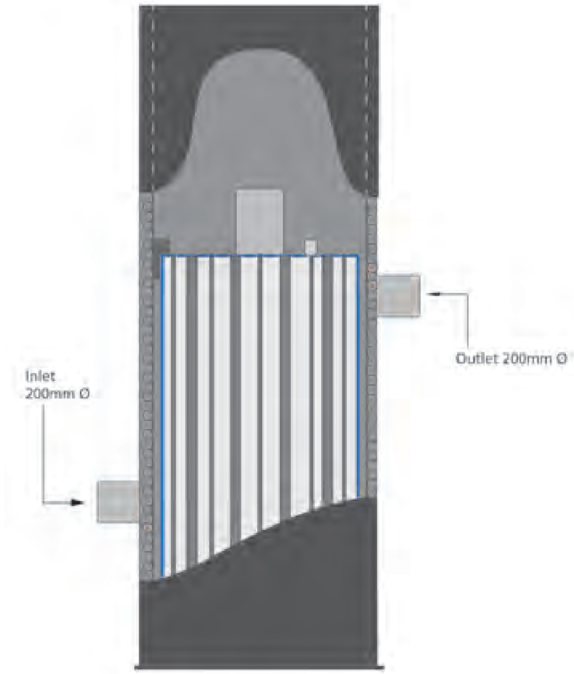
Note
1) Initial flow capacity during normal operation. Flow capacity will deteriorate over time, the rate of flow attenuation dependant on the contamination load within the run-off.

Water Treatment Benefits

The RIDGISTORMSeparate-X4 is a DiBT and NJDEP certified Proprietary multi-process treatment system with an SMI value of 0.8 in all three categories (TSS, Metals and hydrocarbons) of the CIRIA C753 SuDS mitigation indices.



The table below details a number of key pollutants that may typically be contained within surface water run-off from a main distributor road, and the level of pollutant treatment offered by the RIDGISTORMSeparate-X4 unit (within the final column).



Idealised RIDGISTORMSeparate-X4 and prefabricated chamber

Parameter	Unit	Main distributor road		X4
		From	To	Aim
Physio-chemical parameters				
Electrical conductivity	[uS/cm]	110	2400	<1500
pH value	[-]	6.4	7.9	7.0 - 9.5
NUTRIENTS				
P tot	[mg/L]	0.23	0.34	0.10
NH_4	[mg/L]	0.5	2.3	0.3
HEAVY METALS				
Cd	[µg/L]	0.3	13.0	<1.0
Zn	[µg/L]	120	2000	<500
Cu	[µg/L]	97	104	<50[1]
Pb	[µg/L]	11	525	<25[1]
Ni	[µg/L]	4	70	<20
Cr	[µg/L]	6	50	<50
ORGANIC SUBSTANCES				
PAH (EPA)	[µg/L]	0.2	17.1	<0.2
MOTH	[mg/L]	0.1	6.5	<0.2

Note
1) For copper and lead roofs a second treatment step is necessary.

INTRODUCTION
4.1 PERMATREAT & PERMACHANNEL
4.2 RIDGITREAT
4.3 OUTFALL HEADWALL
4.4 RIDGISTORM SEPARATE
4.5 RIDGISTORM SEPARATE-X4
4.6 RIDGISTORM CHECK
4.7 PERMAVOID ANCILLARIES
4.8 PERMAVOID PASSIVE IRRIGATION SYSTEM
4.9 RAINSTREAM – RAINWATER CAPTURE AND REUSE
4.10 MORE WE CAN DO

4.6 RIDGISTORMCheck

Polypipe is able to offer a range of fabricated chambers which can be manufactured with numerous features that offer surface water hydraulic management options.

Polypipe's range of thermoplastic structured walled pipe systems can be utilised to form the chamber wall, summarised in the table below.

RIDGISTORMCheck	
Nominal chamber diameter [mm] available as standard	750, 900, 1050, 1200, 1500, 1800, 2100, 2400, 2700 & 3000

RIDGISTORMCheck Chamber Units are fabricated with the appropriate connecting pipe work to allow simple integration within the proposed drainage scheme. The units can also be supplied with a full range of ancillary items including step rungs, ladders and lifting points. For further details of the numerous options available with this system, please refer to the 'Four Step Guide to Ridgistorm-XL Pre-Fabricated Component Chambers' which can be found at polypipe.com/literature-search.

4.6.1 Orifice Plate Flow Control

RIDGISTORMCheck Orifice Plate Flow Control Chambers offer a cost-effective means of limiting flows, particularly when used in conjunction with our range of attenuation systems on smaller scale projects.

Where flows within the drainage system are required to be controlled to a predefined flow rate (i.e. prior to discharge from site), we are able to offer our RIDGISTORMCheck Orifice Plate Flow Control Chamber. The unit is fabricated with an orifice plate at the chamber outlet, with the diameter of orifice to suit the drainage system hydraulic design.

An optional removable Permavoid filter unit can also be supplied for the outlet; the Permavoid filtration unit wrapped in a 2mm polyethylene mesh to provide an additional level of filtration, which can be easily removed to facilitate maintenance.

Hydraulic Benefits

The primary function of the RIDGISTORMCheck Orifice Plate Flow Control Chamber is to control the rate of the surface water flow discharged from the unit in order to protect downstream drainage systems and maximise the utilisation of upstream attenuation storage – where it forms part of the drainage design.

Water Treatment Benefits

When supplied with the optional removable Permavoid filter unit, the filter unit offers surface water pollution management options to control silts and debris, prior to its discharge into the downstream drainage system.

4.6.2 Vortex Flow Control

RIDGISTORMCheck Vortex Flow Control Chambers incorporate a vortex flow control unit, fitted onto a preformed headwall.

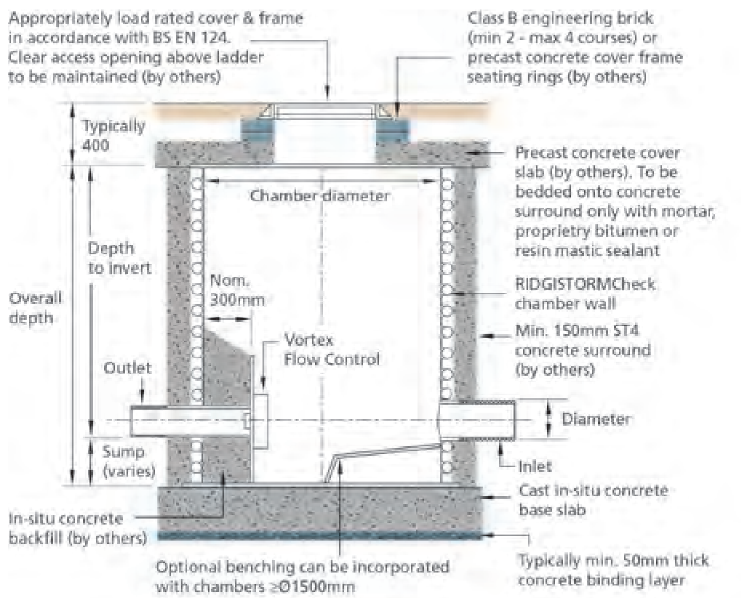
The vortex flow control unit is manufactured to suit the unique hydraulic characteristics of the site's drainage system design. RIDGISTORMCheck Vortex Flow Control Chambers are typically supplied as a single unit, allowing simple installation.

When installed in conjunction with Polypipe's range of pipe systems, they offer a fully integrated drainage system.

Hydraulic Benefits

The primary function of the RIDGISTORMCheck Vortex Flow Contro water discharged from the unit in order to protect downstream drainage systems.

Where it is used to maximise the utilisation of upstream attenuation storage, a vortex flow control unit can offer hydraulic benefits when compared with an orifice flow control chamber. The rate of discharge through a vortex unit can better match a prescribed discharge limit, for a wider range of water depths. Provided the water volume discharged from the development does not exceed the volumes associated with the site's pre-development state, this can reduce the attenuation storage volumes within the development.



4.7 Permavoid

Polypipe Permavoid is an engineered high strength modular geocellular system designed as a combined drainage component. When installed with the appropriate geosynthetic(s), it may be utilised to provide surface water attenuation, infiltration and retention.

The Permavoid system utilises a proprietary interlocking connector that allows adjoined units to behave as a continuous structural system, ideally suited for shallow installations within trafficked areas, i.e. a permeable pavement sub-base replacement system. The inherent flexibility of the modular system, along with the unit strength characteristics, have also enabled Polypipe to offer a number of additional innovative surface water management solutions using these units; the product benefits and typical application are detailed within this section.

4.7.1 Permavoid Rainwater Diffuser Unit

The Permavoid Rainwater Diffuser Unit is a pre-fabricated unit, formed from a number of Permavoid units, encapsulated in a 2mm mesh fabric.

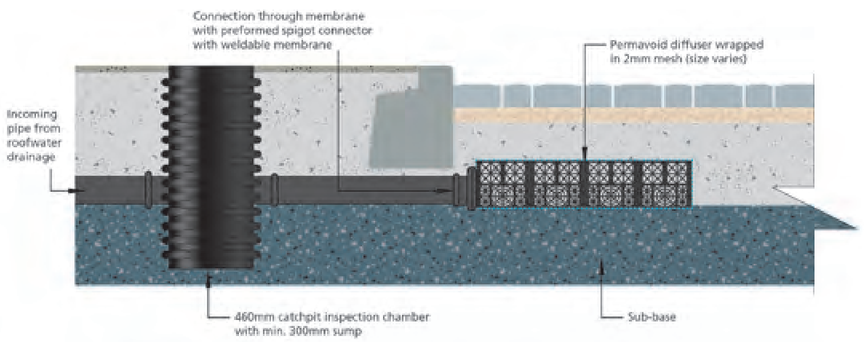
Available in a number of standard unit configurations to suit the expected volume of surface water inflow. Designed to provide a simple method of incorporating filtered stormwater, point source discharges into the sub-base of a permeable pavement.

Unit characteristics are summarised below.

Rainwater Diffuser Unit	
Dimensional Options	
Height [mm]	150, 300
Width [mm]	354, 708, 1062 [1], 1416, 2124
Length [mm]	708, 1062 [1], 1416, 2124
Intrinsic permeability, k [m^2]	1.0 x 10^{-5}
Inlet connector option [mm]	110, 160 (BS EN 1401-1 socket)

Note
1) Unit option with plan dimensions 1062 x 1062mm is not available.

A typical application would be where the above ground downpipe from a building's roof drainage system flows into a back inlet gully; where the gully does not incorporate an internal filter, it is recommended that the surface water is then drained to a catchpit inspection chamber (i.e. RIDGISTORMSeparate Silt Trap unit); the back inlet gully, or chamber, then discharging the filtered stormwater into a permeable sub-base via Permavoid Rainwater Diffuser Unit – the run-off diffusing out of the Permavoid Rainwater Diffuser Unit and into the modified granular sub-base layer.



Permavoid Rainwater Diffuser Unit typical installation detail

4.7.2 Permaceptor

The Permaceptor is a pre-fabricated unit that is designed to be used with conventional road/yard gullies, providing additional water quality management of oil and silt that may be contained within gully discharges prior to its entry into the downstream drainage system.

Ideally installed as close as possible to the conventional gully's outlet, at a zero or near zero gradient, the unit functions as a gravity silt and oil interceptor and treatment system.

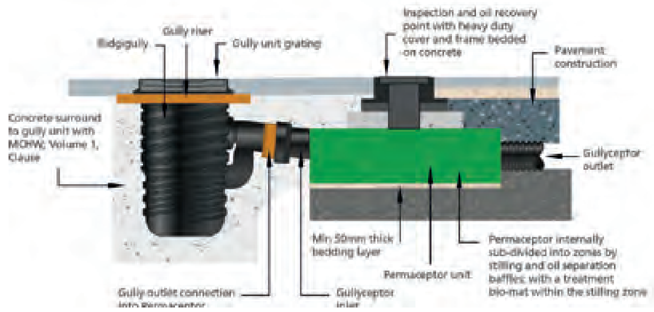
The Permaceptor unit can be sized to suit the expected discharge rate from the upstream gully.

The unit outlet discharges via a weir and baffle arrangement that is designed to capture oils and silt, preventing them from progressing into the rest of the drainage system.

Unit characteristics are summarised in table below.

Permaceptor	
Height [mm]	300
Width [mm]	708
Length [mm]	1062

Note
1) Alternative unit dimensions available upon request.



Hydraulic Benefits

The Permaceptor's initial function is to slow down sheet surface water run-off flows from each sub-catchment; thereby increasing the retention time of the surface water at source.

Water Treatment Benefits

Permaceptor's initial function of slowing down surface water run-off flows, is to encourage silt deposition within the unit. In addition, the primary zone created within the unit, contains a floating biomat to intercept floating hydrocarbons.

The biomat is formed from a proprietary blend of hydrophilic and hydrophobic fibres. The proprietary blend of fibres is designed to retain hydrocarbons; in addition to maintaining a level of moisture that encourages biofilm formation, thereby creating an environment where aerobic biodegradation of the retained hydrocarbons can occur.

Typical water management control offered by the unit is given in the table below.

Nominal Water Pollution Removal Efficiency	
Intrinsic permeability, k [m^2]	1.0 x 10^{-5}
Oil retention [g/m^2]	56.0
Effluent discharge at max oil loading [ppm]	10

Note
1) Expected water pollution control. [1]

1. Puehmeier, T and Newman A.P (2008) Oil Retaining and Treating Geotextile for Pavement Applications.

4.7.3 Permavoid Biomat

Permavoid Biomat is a high strength Permavoid geocellular unit, containing a low density, oil treating, geosynthetic floating mat (biomat).

The biomat floats on water and is designed to intercept and treat any potential residual emulsified oils that may be present within the surface water.

The unit is designed to form part of an underground geocellular structure, positioned to coincide with proposed pipe inlet connections to the structure, providing additional oil retention and water treatment capability within an underground geocellular infiltration or attenuation storage installation.

Unit characteristics are summarised in the table below.

Nominal Device Characteristics	
Height [mm]	150
Width [mm]	708
Length [mm]	1062

Note
1) Individual units may be connected to form an installation with a larger surface area; increasing the level of treatment efficiency offered, or accommodate larger volumes of water discharging into the system.

Hydraulic Benefits

The Permavoid Biomat unit is designed to be incorporated within a standard Permavoid geocellular installation. Therefore, when used in this manner, these units do not introduce an additional element into the drainage system that could essentially increase head loss or a requirement for an invert level difference across the hosting installation.

Nominal Water Pollution Removal Efficiency	
Intrinsic permeability, k [m^2]	1.0 x 10^{-5}
Oil retention [g/m^2]	56.0
Effluent discharge at max oil loading [ppm]	10

Note
1) Expected water pollution control based on. [1]

Water Treatment Benefits

The biomat floats on water and is designed to intercept and treat any potential residual emulsified oils that may be present within the surface water.

As with Permaceptor, the biomat is formed from a proprietary blend of hydrophilic and hydrophobic fibres. The proprietary blend of fibres designed to retain hydrocarbons; in additionto maintaining a level of moisture that encourages biofilm formation, thereby creating an environment where aerobic biodegradation of the retained hydrocarbons can occur.

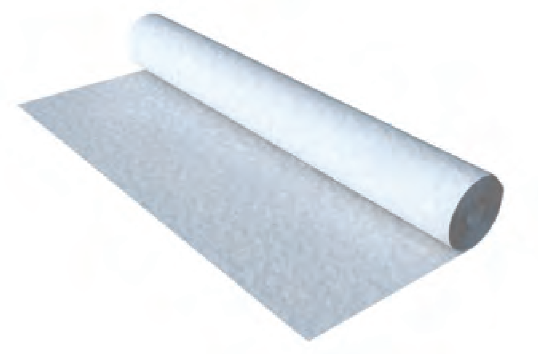
Typical water management control offered by the unit is given in the table to the right.

4.7.4 Permafilter Geotextile

Permafilter Geotextile is a non-woven, dimpled, needle punched geotextile that's been specifically designed for hydrocarbon pollution treatment in sustainable drainage systems (SuDS) and other civil engineering applications.

Suitable for a wide range of applications, Permafilter Geotextile's proprietary blend of polyester fibres incorporates hydrophilic (water attracting and oil repellent) and hydrophobic (oil attracting and water repellent) properties to achieve superior oil retention. It's therefore capable of retaining oil contamination ranging from daily car drip losses up to catastrophic spillages. The entrapped hydrocarbons are then biodegraded by naturally occurring microorganisms providing a self-cleansing mechanism.

Permafilter Geotextile's high-performance capabilities allows for use in applications ranging from podium decks, cycle paths and tree protection to permeable pavements, infiltration tanks and swales.



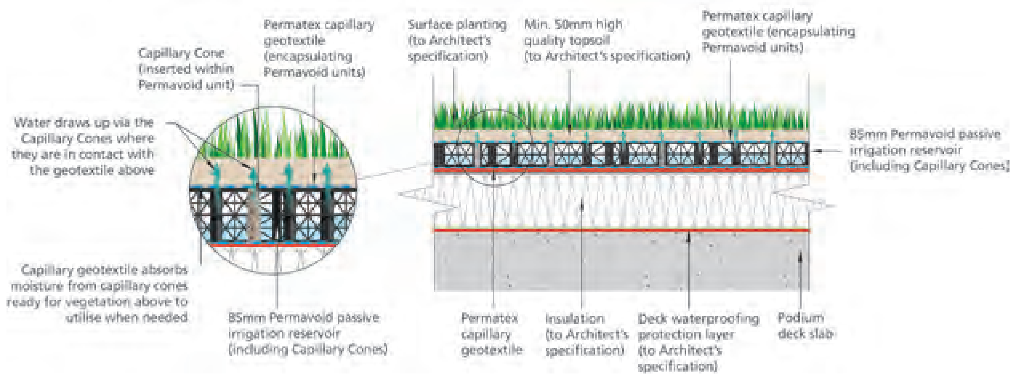
Element	Value
Physical properties	
Weight	$300g/m^2$
Roll length	100m
Roll width	2.4m
Roll weight	72kg
Mechanical properties	
Tensile strength EN10319 (md/cmd)	9/12kN/m
Static puncture (CBR test) EN12236	1575N
Hydraulic Properties	
Water permeability EN ISO 11058	57 $l/m^2/s$
Other properties	
Air permeability	1000 $l/m^2/s$
Max. oil retention	$6L/10m^2$
Effluent discharge at max. spacing oil loading	10ppm
Material	Modified polyester

1. Puehmeier, T and Newman A.P (2008) Oil Retaining and Treating Geotextile for Pavement Applications.

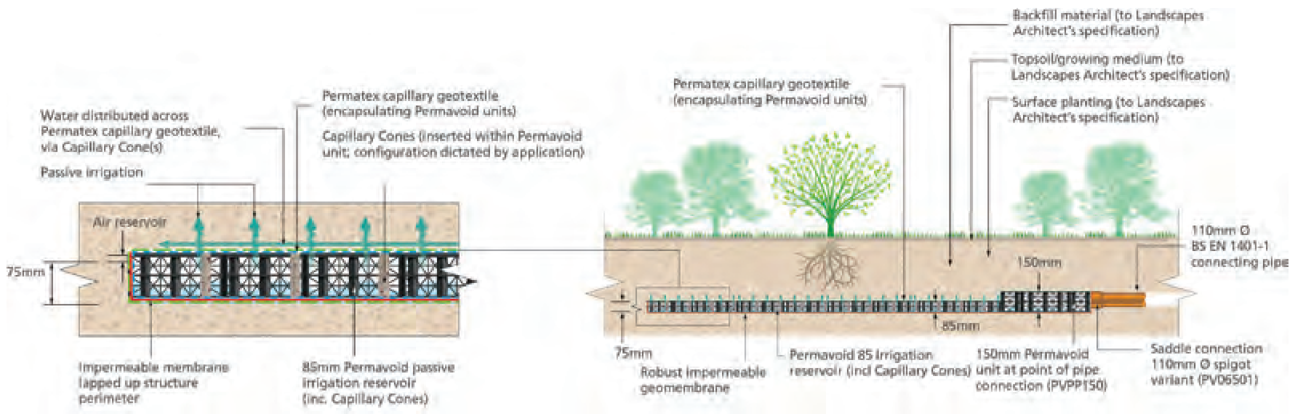
4.8 Permavoid Passive Irrigation System

Polypipe Permavoid is an engineered high strength modular geocellular system designed to be used as a combined drainage component. When the relevant elements from the system are installed with the appropriate geosynthetic(s), it may be utilised to provide passive irrigation to overlying vegetation, in addition to surface water attenuation or infiltration if required.

This section details the various Permavoid system elements that may be used to provide a passive irrigation system, which when designed as part of a sustainable drainage system, does not require additional water or energy inputs to operate.



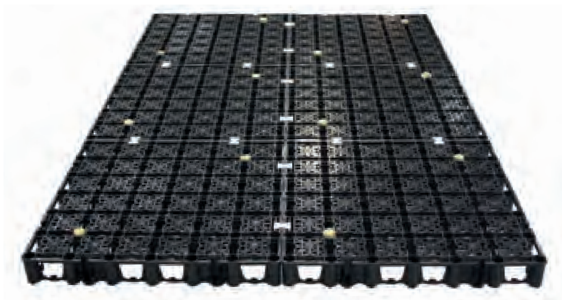
Typical section through Permavoid Podium Deck roof garden showing Permavoid² 85 Irrigation



Typical section through Permavoid irrigation system at pipe connection

4.8.1 Permavoid² 85 Irrigation

The Permavoid² 85 Irrigation comprises six pre-connected units with an integral wicking media and is designed to provide attenuation and irrigation for shallow non-loaded applications.



The stored water is carried up through the cell via absorbent capillary cones using capillary action and, in conjunction with Permavoid Permatex Capillary Geotextile, is spread laterally across the surface area. Ideal for use in the most diverse roof and podium deck applications, enabling extensive and intensive greening, alongside hard landscaping. It is 85mm high, manufactured from recycled polypropylene and minimises installation time.

Key Benefits

- Enables surface water management and makes space for water in urban environments
- Provides passive irrigation by maintaining saturation of the wicking geotextile at 55-65%
- Allows the wicked stormwater to spread across a large surface area, ensuring plants have soil moisture to promote growth
- Minimises evaporation and over spraying losses associated with above ground irrigation systems
- Can be installed as part of an intelligent water management system, which can be controlled and monitored remotely
- High capacity, shallow, sub-base replacement system for non-trafficked applications
- 93% void ratio provides excellent storage capacity
- Plan area of 3m² maximises unit coverage, increasing laying efficiency
- Manufactured from recycled material
- Design life in excess of 50 years
- 100% recyclable at the end of its service life

Applications

Permavoid² 85 Irrigation is designed for use in applications that will not be exposed to traffic loading, including:

- Green roofs
- Blue roof gardens
- Soft landscapes areas
- Raised planters
- Sports pitches

For non-irrigation applications, please see our Permavoid² 85.

Permavoid² 85 Irrigation	
Dimensional Options	
Depth [mm]	85
Width [mm]	1424
Length [mm]	2136

Note
1) The Permavoid system is based on a modular geocellular unit; the flexibility of the system allows individual units to be connected to form larger capacity installations.

Nominal Hydraulic Properties	
Volumetric void ratio [%]	93
Storage capacity [litre]	242.4

Note
1) Stated unit storage capacity is typically sufficient to maintain soil moisture content of the overlying substrate in excess of 15%, for extended periods of time.

Installation

All calculations for Permavoid units are based upon site-specific load cases, pavement construction types and thicknesses, soil cover and ground conditions and the suitability must therefore be approved for each project.

4.8.2 Permafoam Unit

The Permafoam unit is an open-celled, phenolic foam incorporated into a high-strength Permavoid geocellular unit. Permafoam is highly absorbent and water-retentive, with the ability to retain a significant volume of water.

The structure of the Permavoid unit protects the foam from damage or compaction from imposed backfill or traffic loads.

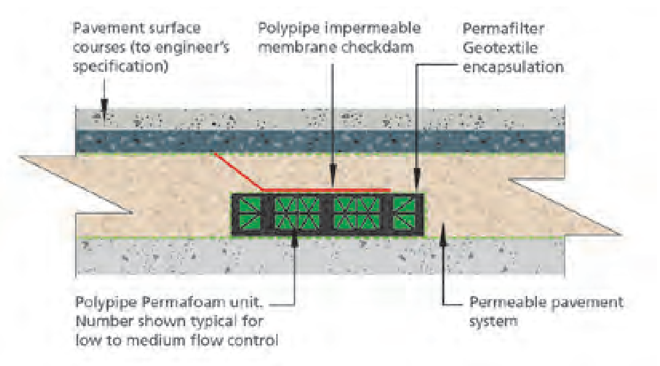
The units are typically used for 'on-demand' irrigation within landscaped areas; installed in conjunction with the Permatex capillary geotextile, the Permafoam units are used to facilitate stormwater collection. Permafoam units may also be used to form check dams and gates within a permeable pavement sub-base laid over steeply sloping surfaces, providing velocity control of inter-pavement drainage flows. Due to the unit's significantly larger surface area, compared to traditional check-gate flow control, Permafoam has a lower associated risk of clogging.

Unit characteristics are summarised in the table below.

Permafoam	
Dimensional Options	
Height [mm]	85 or 150
Width [mm]	354
Length [mm]	708

Note
1) The Permavoid system is based on a modular geocellular unit; the flexibility of the system allows individual units to be connected to form larger capacity installations.

Permafoam	85mm	150mm
Volumetric void ratio	83%	1000
Storage capacity (foam)	Up to 17.6 L	Up to 31 L
Water permeability (in plane flow)	0.0452 Litres/second/lin. m.	0.0452 Litres/second/lin. m.

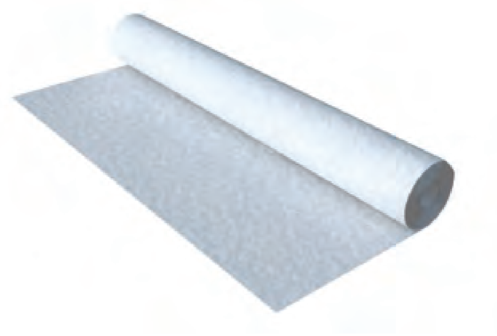


Typical section through permeable sub-base with membrane checkdam and Permafoam checkgate (low flow)

4.8.3 Permatex Capillary Geotextile

The Permatex Capillary Geotextile is a heavy-duty, non-woven, needle punched geotextile made from UV stabilised polypropylene. Specifically formulated to absorb water and distribute it across the geotextile, which when constantly charged with water allows moisture to be fed naturally by capillary action to irrigate overlying mineral substrates.

Used in conjunction with Permavoid Capillary Cone units, the geotextile enables the even distribution of water across the whole interface area of the overlying soils and Permavoid Capillary Cell installation.



Hydraulic Benefits

The water management control characteristics offered by the Permatex Capillary Geotextile is given in the table below.

Permatex Capillary Geotextile	
Hydraulic properties	
Water retention capacity	1.14l/m²
Dynamic cone drop	17mm
Opening size 0-90	95 microns
Horizontal capillary distance in conjunction with capillary cones	Min. 750mm for sports mixes

Note
1) All values stated above are nominal and may vary within manufacturing tolerances.

Rainstream – Rainwater Capture and Reuse

Rainwater capture and reuse systems are designed to capture, store, treat and reuse a volume of run-off water from roofs, podiums and other impermeable surfaces within the footprint of the property that it is designed to serve.

The Polypipe capture and reuse system can be fully integrated into Polypipe source control systems such as roof and podium attenuation. Furthermore, it can be integrated to support amenity and biodiversity by inclusion within our Blue-Green roof system to provide water for irrigation through our passive irrigation methods such as drip feed and spray irrigation.

Polypipe offers three distinct control methods for surface water capture and reuse to include a direct system, a gravity system and a hybrid system. The hybrid system offers benefits for high peak demand applications such as schools whereby pump size and associated pipework diameters can be reduced in order to save space and power usage.

4.9 Overview of different systems

Polypipe Direct System

Rainwater run-off is fed via gravity drainage pipework to a sized tank either underground or within the building (basement/mechanical service level). Pre-tank treatment reduces ingress of organic matter into the tank and in-tank/post tank treatment is provided dependent on the reuse application. The tank shall have an overflow connected to a downstream drainage system.

A non-return valve is fitted to the overflow to prevent contamination of the tank from surcharging drains. Reuse water is returned directly to the appliance via a pumped pressurised return pipe system; pumps are activated when a pressure drop is measured in the feed pressure pipe (the pipe shall be marked as non-potable). Tank levels, pump rates and other system attributes will be managed by a control system and associated components. The tank can be topped up with potable water if required however the potable water supply and the reuse water must be kept apart to prevent cross contamination (WRAS approved air gap).

4.9.1 Polypipe Rainstream System

Polypipe will give design guidance on the capture and reuse system using recommended industry guidelines.

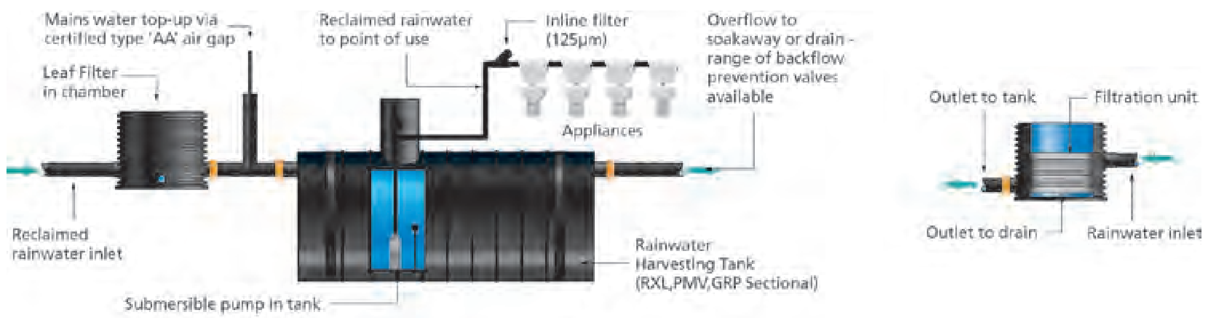
Water supply pipework that is used to convey reuse water back into the building should be marked clearly in accordance with WRAS guidelines. For project assistance please contact us.

Multifunctional benefits

SURFACE WATER MANAGEMENT
Reduces total volume of water discharged into the drainage system.

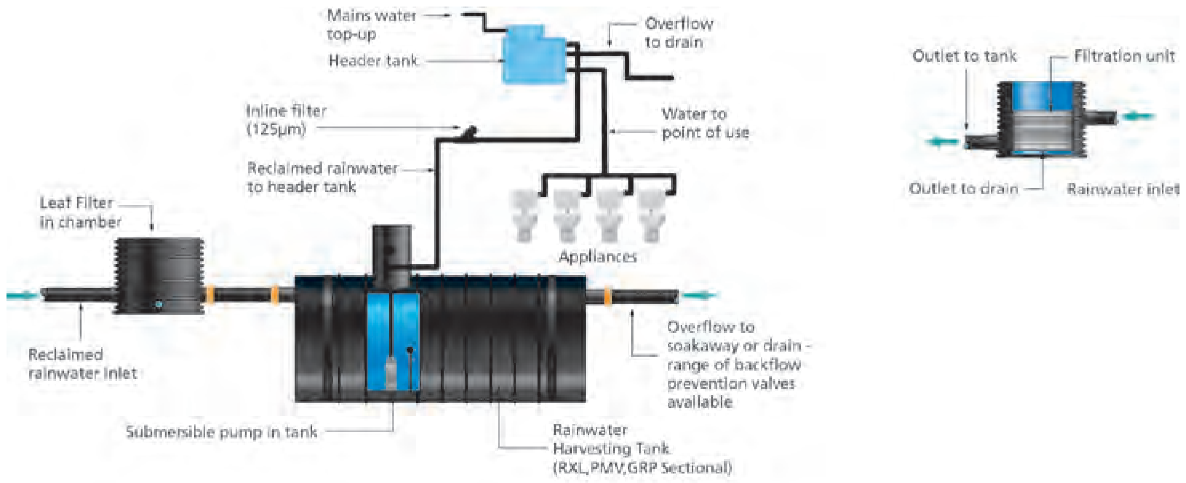
Guidance for the detailed design of reuse systems are given in:

- SuDS Manual (C753) guidance – Chapter 11 Rainwater Harvesting
- BS EN 16941-1:2018 On-site non-potable water systems
- BS 8542:2011 Calculating domestic water consumption in non-domestic buildings
- BS 8595:2013 Code of practice for the selection of water reuse systems
- EA (2010) Harvesting rainwater for domestic uses: an information guide
- BS EN 12056-3:2000 Gravity drainage systems inside buildings. Roof drainage, layout and calculation
- WRAS Water Regulations Guide



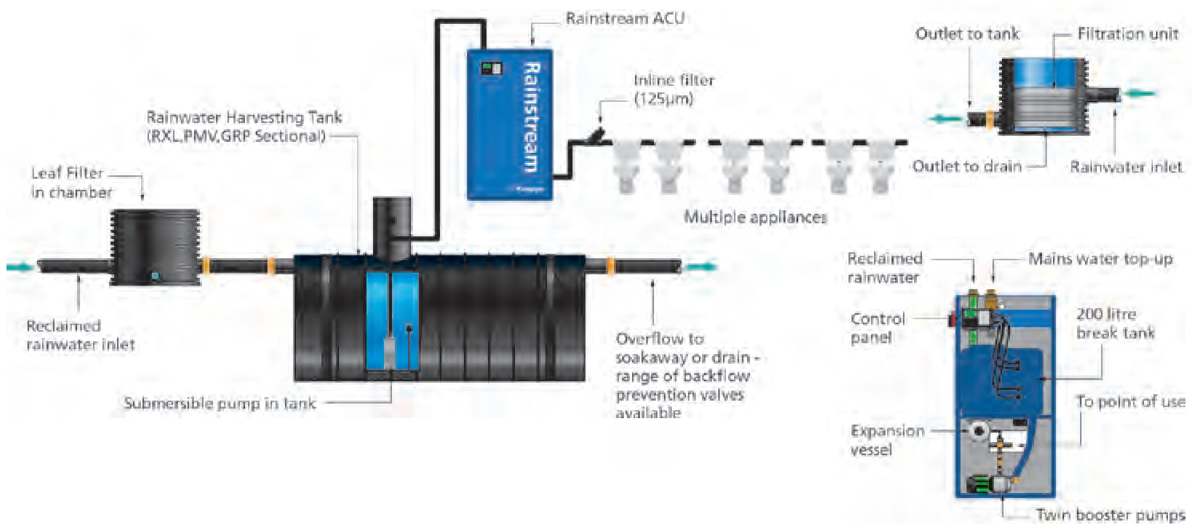
Polypipe Gravity System

Rainwater run-off is fed via gravity drainage pipework to a sized tank, either underground or within the building (basement/mechanical service level). Pre-tank treatment reduces ingress of organic matter into the tank, and in-tank/post tank treatment is provided dependent on the reuse application. The tank has an overflow connected to a downstream drainage system, whilst a non-return valve is fitted to the overflow to prevent contamination of the tank from surcharging drains. Reuse water is returned to a header tank within the building via a pumped pressurised return pipe system; pumps are activated when a pressure drop is measured in the feed pressure pipe (the pipe would be marked as non-potable). Reuse water is fed to the appliance via gravity from the header tank, whilst the level control in the header tank is determined via a header tank ball valve, with supplementary level sensors being installed if required by the control system. The header tank can be topped up with potable water if required, however the potable water supply and the reuse water must be kept apart to prevent cross contamination (WRAS approved air gap).



Polypipe Hybrid System

The Polypipe Hybrid System follows the concept of the direct system. A Rainstream ACU incorporating a break tank is inserted in the supply line from the storage tank to the appliance and reuse water is supplied direct to the appliance, via pump sets. Potable water top up is installed to the break tank via a WRAS approved air gap with the control for the entire system being located n the Rainstream ACU.



4.9.2 System Tank Options

Polypipe Ridgistorm-XL Tanks (Below Ground)

Polypipe Ridgistorm-XL tanks shall be selected for below ground installations. The geometry of the tank and its stiffness class can be varied to suit the below ground space, the volume of water required to be stored and the geotechnical conditions. The tanks are fabricated using advanced polymer welding techniques and can be configured to include access/plant turrets, integrated access steps and other equipment. Ridgistorm-XL fabrication is also used to provide chambers for pre-tank filtration and other appliances. The Ridgistorm-XL tank can be manufactured to include a silver ion impregnated inner tank wall which prevents bacteria attachment and reduces the opportunity for biological growth.

Polypipe Permavoid Tank (+ Podium and roof level)

Polypipe Permavoid tanks shall be selected for roof and podium installation. The geometry of the tank can be adjusted to store the requested volume of water within the footprint of the building roof or podium. The tanks are encapsulated with geomembrane which is welded in-situ.

Polypipe Sectional Tanks – GRP Tanks (Above Ground)

Polypipe GRP sectional tanks shall be selected for above ground installation. The geometry of the tank can be adjusted to store the requisite volume of water within a confined space and proprietary products can be used to form the pre-tank filtration.

The tanks are sectional with the sections being sealed and bolted together on-site.

4.9.3 Treatment

The treatment hierarchy that we design can be considered to be part of the control of pollution from site surface water run-off under a SuDS Management Train as well as treating the collected water to be of adequate quality for reuse (by application).

If multi-purpose reuse is required then all water shall be treated to the highest application level, i.e. if the reuse is for toilet flushing and vaporised spray irrigation then the higher level of treatment required for vaporisation shall be selected.

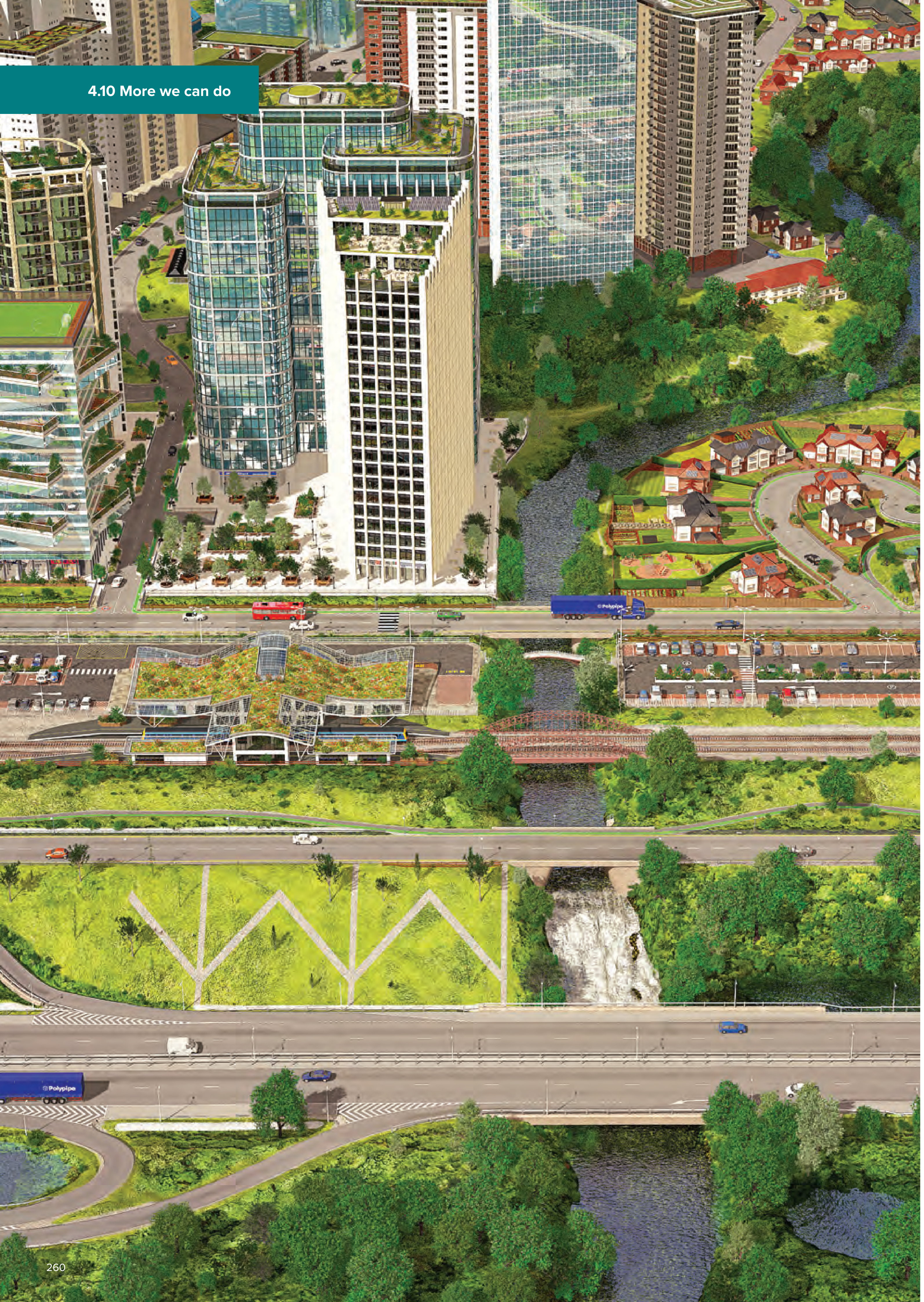
We have several treatment products to improve water quality. The RIDGISTORMSeparate-X4 unit is able to filter out heavy metals and hydrocarbons and prevent them from entering the storage tank. Our UV and titanium dioxide disinfection units provide protection against bacteria entering the reuse supply system – and our silver ion lined tank wall prevents attachment of bacteria colonies to the RIDGISTORM-XL tank wall.

4.9.4 Operation and Maintenance

Polypipe will supply an operating manual with each system which details the system operation, components used and a troubleshooting matrix. Included within the manual is a maintenance matrix showing periodic inspection and timescales between inspection.

Inspection and Maintenance

System Component	Operation	Notes	Frequency
Gutters/Downpipes	Inspection/ Maintenance	Check that there are no leaks or blockages due to debris; clean the gutters if necessary	Annual – Especially Autumn
Leaf Filter	Inspection	Check that there are no leaks, that there has been no build up of debris and that the tank is stable and the cover correctly fitted	Biannually – at least after Autumn
	Maintenance	Drain down and clean the tank	Every 10 years
	WARNING!	Human entry into tanks should be avoided where possible. Where entry is essential, it should only be undertaken by trained personnel with personal protection equipment suitable for confined spaces	
Floating Filter (in tank)	Maintenance	Remove and clean	Every 2 years
Pumps and Pump Control	Inspection/ Maintenance	Check that there are no leaks and that there has been no corrosion; carry out a test run; check the gas charge within the expansion vessel or shock arrestors	Annually
Back-up Water Supply	Inspection	Check that the back-up supply is functioning correctly, that there are no leaks and that the air gaps are maintained	Annually
Control Unit	Inspection/ Maintenance	Check that the unit is functioning appropriately, including alarm functions - also see troubleshooting section for further details on correct functionality	Annually
Wiring	Inspection	Visually check that the wiring is safe	Annually
Pipework	Inspection	Check that there are no leaks, that the pipes are watertight and that overflows are clear	Annually
Markings	Inspection	Check that warning notices and pipework identifications are correct and in place	Annually
Support and Fixings	Inspection/ Maintenance	Adjust and tighten, where applicable	Annually
UV lamps	Maintenance	Inspect and clean UV Unit Quartz tube	Every 6 months
	Inspection/ Maintenance	Pay attention to alarm messages - see troubleshooting section for alarm descriptions	Upon alarm
	Maintenance	Replace pre-filter	Every 6 months
In-line Filter	Inspection/ Maintenance	Remove and clean	Every 4 months
Supplied Rainwater	Inspection/ Maintenance	Inspect visual appearance and odour of supplied rainwater. If poor water quality is suspected, samples should be taken and tested in accordance with BS EN 16941-1	Annually
Notes: General - R.C.D.	Maintenance	Test the R.C.D regularly	As per instructions on R.C.D
	Inspection/ Maintenance	Where fitted, check the air pressure in the well-head pressure vessel	Every 6 months



There's always more we can do

Whilst this Guide is a comprehensive look at how climate change has triggered a real need to adapt within the construction industry, and how our products and systems – together with technical information – can help reintroduce green spaces to mitigate the negative effects, there is still much to discover.

Our interactive Green Infrastructure website provides useful information to keep you up to date with news and innovations as they happen, providing an interactive and intuitive experience and includes news, technical and product detail and everything Green Urbanisation.

To find out more visit **polypipe.com/green-infrastructure**

And Polypipe Tech Hub and BIM modelling will ensure you're able to design the most effective system to deliver a sustainable project; providing products that work together, saving time and reducing costs, whilst contributing to a more resilient future.

For more information, visit **polypipe.com/civils-technical-hub**

The company

Through experience, constant innovation and focused research and development, Polypipe is uniquely positioned to help professionals create engineered water and climate management solutions that enable a sustainable built environment.

Engineered Piping Systems

At the heart of Polypipe are our core engineered piping systems, which enable the movement of water and air. Used in some of the most prestigious buildings and infrastructure projects for over 40 years, Polypipe's piping systems have become the benchmark for quality and performance. From a 15mm diameter pressurised internal plumbing system to a 3m diameter trunk sewer, Polypipe has the solution to enhance your project.

Water Management Solutions

Since Polypipe began in 1980, we've been developing new and innovative drainage solutions to improve and manage the conveyance of surface water. Creating systems that are not only sustainably produced, but that enhance sustainability in their installation and everyday use. Originally conceived in 2004, Polypipe's surface water attenuation, infiltration and treatment solutions, combined with our engineers' understanding of application and regulations, have firmly established Polypipe as a market leader in stormwater management. More recently, our continued investment has delivered a significant step forward towards inspiring greener urban environments – Green Urbanisation that complements our built environments with important Green Infrastructure. Engineered products and systems that make space for water, whilst helping create green spaces, enabling amenity and encouraging biodiversity.

Climate Management Solutions

As a world leader in the design and manufacture of fans and ventilation systems, we are shaping the performance of indoor climates. By pushing the boundaries of performance and carbon reduction, we continue to lead the industry and help clients deliver greener homes and buildings with the highest levels of indoor air quality. Put simply, we make built environments better, more energy-efficient, more comfortable to live in and cleaner.

Our market sectors

All of our businesses are aligned to their specific market sectors, and each have their own vocation-specific specialist teams – so we understand the needs of our customers, and use our specialist knowledge of the applications we serve to provide support to them on the best designs or product applications for their projects. For the solutions you need within civil engineering, plumbing or mechanical ventilation, Polypipe has the people to help and the forward-thinking to succeed.

Civils and infrastructure

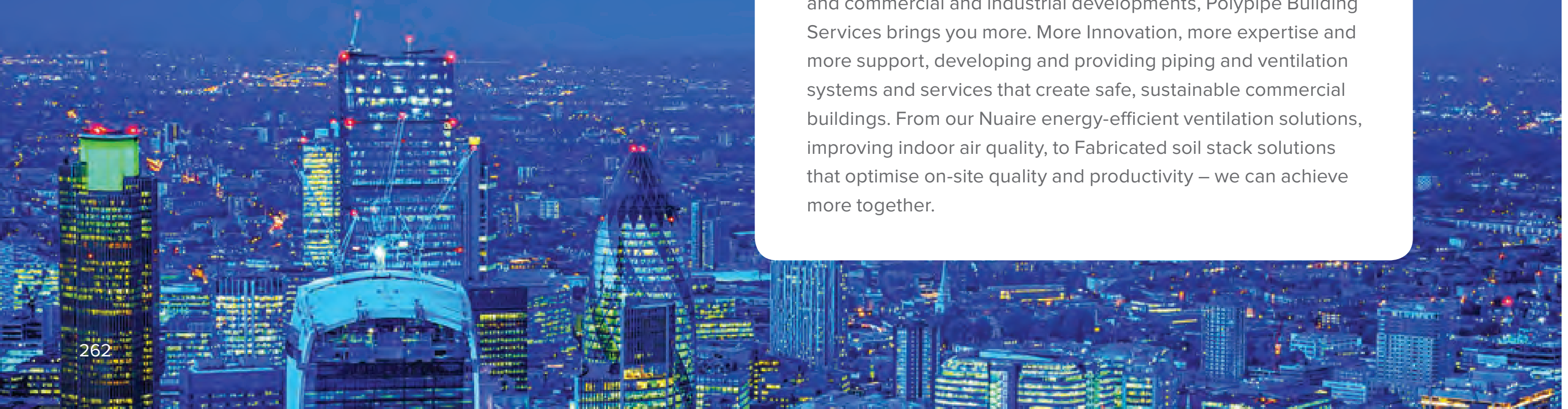
With our Civil Engineering application experience, we are able to create intelligent water management solutions and provide specialist support, delivering the widest range of surface water management, sewer systems and cable protection for roads & highways, power, ports & harbours, rail and commercial infrastructure.

Residential

Whether for new build or refurbishment projects, our Building Products business specifically recognises the demands of constructing modern residential buildings. Together with National and Local Developers in both private and social housing, we have specialist teams working with Plumbers and Heating Engineers, General Builders, Groundworkers and National and Independent Merchants to bring together a successful project. From the only Kitemark® accredited traps range, our market-leading Domus range of energy efficient ventilations systems and innovative underfloor heating products, to our above and below-ground drainage systems, rainwater solutions and the largest range of plastic hot and cold plumbing products – we have a solution for every application.

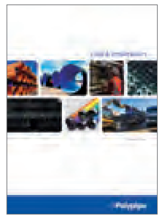
Building Services

From schools, hospitals and tall buildings to shopping centres and commercial and industrial developments, Polypipe Building Services brings you more. More Innovation, more expertise and more support, developing and providing piping and ventilation systems and services that create safe, sustainable commercial buildings. From our Nuaire energy-efficient ventilation solutions, improving indoor air quality, to Fabricated soil stack solutions that optimise on-site quality and productivity – we can achieve more together.



Literature

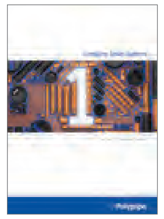
All of our literature is available at **www.polypipe.com/toolbox**



Polypipe Civils and Infrastructure Product Guide

Polypipe Civils and infrastructure Pocket Guide

Drain and Sewer Technical Manual

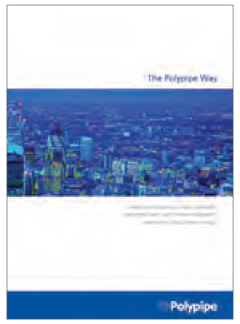


Complete Sewer Systems

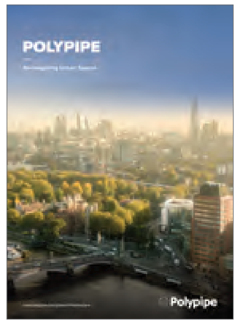
Polypipe Smart Roof 2.1

Support literature

Everything you need to know about how Polypipe can help you make your projects the best they can be; from our expertise, knowledge and capability to our products to inspire important Green Urbanisation and make space for water, can be downloaded at **polypipe.com/toolbox**



The Polypipe Way
+44 (0)1709 770000



Re-imagining Urban Spaces
+44 (0)1509 615100

Polypipe Building Services
+44 (0)1622 795200

6.0 Glossary

Amenity: In the context of this brochure, amenity is a piece of construction or place that's been created implementing Green Infrastructure; bars, roof gardens, green corridors, where people can visit, enjoy and utilise on a general basis.

Anaerobic: In its simplest term, anaerobic means a lack of oxygen. In the context of this brochure, an anaerobic atmosphere is a result of a lack of green spaces, natural vegetation and the subsequent Urban Heat Island effect.

Balanced Scorecard: The Balanced Scorecard ensures that value for money is fully considered, whilst bearing in mind social, economic and environmental factors within the procurement process. This means taking into account the value offered by suppliers, contractors and sub-contractors, the designs put forward, technical specification and contract performance conditions linked to the subject criteria of the contract. Whilst the Approach only applies to contracts worth more than £10m, it's worth adopting where possible, even below this figure, to help include and deliver Blue-Green Infrastructure. The Balanced Scorecard is split into Strategic Themes and Critical Success Factors to help make the process easier to procure – a bit like pick 'n' mix for construction – whereby you only need to choose those parts beneficial to achieving value for money.

BBA HAPAS: The British Board of Agrément's Highway Authorities Product Approval Scheme (HAPAS) is a nationally recognised scheme for innovative products and systems used in highways works and construction. Products carrying BBA HAPAS certification are approved for use in highways projects, having satisfied the scheme's stringent quality requirements.

Biodiversity: Biodiversity is the variety of plant and animal life within a particular habitat. In the context of this brochure, we refer to Green Urbanisation and its ability to attract important biodiversity (wildlife) back into our built environments.

Biophilic design: The act of providing natural world attributes, such as green spaces, trees and water, to positively affect human health and productivity – both physically and mentally.

Bioremediation: The process of treating contaminated water, soil or subsurface materials by altering environmental conditions to stimulate the growth of beneficial microorganisms whilst degrading the target pollutants.

Bioretention: Bioretention systems are wildlife habitats and green spaces that remove contaminants from surface rainwater.

Blue-Green Infrastructure: These are green spaces, the results of which are created with engineered SuDS systems but that also make space for water to help the built environment become more resilient against climate change and extreme weather events.

Blue-Green roofs: These are roofs that are constructed to include systems which make space for water and help create Green Urbanisation. This is mostly achieved using Sedum but can include low shrubs and with the use of InfraGreen Tree Boxes, small trees can sometimes be included.

Blue roofs: These are roofs that are constructed to include systems which make space for water by capturing and storing rainwater for reuse. This can be used as part of a rainwater gravity system.

BREEAM points: The Building Research Establishment Environmental Assessment Method (BREEAM) is now recognised as the standard measure of sustainable building design. It addresses environmental and sustainability issues and enables developers to prove the environmental credentials of their buildings to planners and clients through the certified BREEAM assessment rating. A certified rating reflects the performance achieved by a project and its stakeholders, as measured against the standard and its benchmarks. The rating enables comparability between projects and provides reassurance to customers and users, in turn underpinning the quality and value of the building.

California Bearing Ratio (CBR): A penetration test for evaluating the mechanical strength of natural ground, subgrades and base courses beneath new carriageway construction. Harder surfaces are rated with a higher CBR rating, for instance, soft turf may have a rating of 4.75, while high-quality crushed rock has a rating of more than 80.

Capillary cones: Polypipe capillary cones are proprietary products that integrate with our geocellular units to control the amount of water needed to irrigate vegetation above via a wicking process.

CIRIA four pillars: The 'pillars' are set out to ensure that systems are in place to store water, filter water for quality and manage it to help create amenity and attract wildlife. The four pillars of SuDS are – water quantity, water quality, amenity and biodiversity.

Conveyance: In the context of this brochure, Conveyance is the movement of water from one place to another.

DEFRA: The Department for Environment, Food & Rural Affairs. In the context of this brochure, DEFRA is campaigning for more sustainable cities throughout the UK.

Evaporative cooling: Evaporative cooling is the process whereby trees and plants release moisture through their leaves which then cools the surrounding area as it evaporates into the atmosphere.

Evapotranspiration: The process by which water is transferred from the land to the atmosphere by evaporation from the soil and other surfaces and by transpiration from plants.

Geocellular attenuation tanks: Geocellular units that have been manufactured to include a flow control chamber or a permeable membrane.

Geocellular units: These are large, high-strength modular cells. They come in a range of depths for multiple applications and, when used in multiples to create a structural raft, they are able to store, treat and attenuate large volumes of water beneath the surface – whilst also being able to withstand heavy trafficked areas above.

Gravity systems: Gravity Systems collect rainwater from a buildings' roof (via the normal drainage system), filter and store it for reuse in order to reduce the amount of water used from the mains supply, thus reducing the amount of stormwater run-off and helping to lessen the strain on sewer systems.

Green Urbanisation: These are green spaces, the result of which are created with engineered SuDS systems, that develop amenity, cool inner cities and attract biodiversity.

Hydrophilic: Hydrophilic is the action of 'water attracting and oil repelling' properties.

Hydrophobic: Hydrophobic is the action of 'oil attracting and water repelling' properties.

IdentiPol system: A System devised by Thermal Analysis company IdentiPol and used by Polypipe to measure the polymeric properties of each batch of recycled material prior to use.

Impermeable: Impermeable is generally defined as 'unable to get through' and related to materials that are impenetrable by fluids. In the context of this brochure, Impermeable will generally relate to a surface which doesn't allow water to penetrate.

Manning's equation: The Manning's equation is an empirical equation that applies to uniform flow in open channels and is a function of the channel velocity, flow area and channel slope.

National Capital Accounting: In context to this brochure, National Capital Accounting – or NCA – refers to the amount of green space given over for the use of the population to enjoy without gaining any profit from it. The EU's economic prosperity and well-being is underpinned by its natural capital, i.e. its biodiversity, including ecosystems that provide essential goods and services, from fertile soil and multi-functional forests.

Natural water cycle: The natural water cycle maintains a balance of water circulation through evaporation, precipitation, infiltration, groundwater recharge and absorption and transpiration by plants. This can be disrupted with the inclusion of hard landscaping.

Permeable pavement system: A Permeable pavement is one which is made up of either small, separate units (like block paviours) or porous Asphalt which enable surface water to drain and infiltrate through the joints to the soil below.

Photolysis: The chemical process by which molecules are broken down through the absorption of light.

Podium decks: Podium decks are structures that include geocellular units. The system allows for a planted unit which also makes space for water. They can be positioned at roof level, but also at ground level where other amenities such as car parking may be achieved below ground.

Proprietary products: Products specific to Polypipe. In the context of this brochure, Polypipe products that can help enhance the systems for a more successful result.

Roof to River solution: The conveyance of water via water management solutions from interception at roof level of a property, all the way through to discharge at the river. A full water management solution.

Siphonic systems: Designed to rapidly remove large volumes of water, siphonic systems 'suck' water from a surface such as a roof area, with up to ten times the flow capacity of a conventional gravity system. This is achieved using a powerful hydraulic force created by water accelerating down the full height of a building, preventing the ingress of air to rapidly drain water via smaller diameter pipes.

Source control: Products and systems which manage rainwater at the source of interception. i.e. Permavoid geocellular units just below a permeable pavement.

SuDS: Sustainable Drainage Systems (SuDS) – are systems that help manage water effectively. Engineered SuDS are products that form part of a drainage system and include products that ensure rainwater is intercepted at source, stored, treated and attenuated responsibly. Soft SuDS, including natural swales and bioretention gardens, use the natural shape and soils to help with drainage. Both engineered and soft SuDS can be used together to create an effective, on and off-site system to manage and make space for water.

SuDS management train: The conveyance of water via water management solutions from interception, to storage, to attenuation, to eventually discharge downstream at river.

Urban Heat Island effect: Urban Heat Island effect – or UHI – is the result of heat from the sun being absorbed into the concrete of buildings during daylight hours. The buildings trap the heat, especially within confined spaces and without respite from trees and other plants to clean and cool the air. Then at night, when the sun goes down, the concrete releases this stored heat, thus making cities hotter than rural areas.

Volatilisation: The process whereby a dissolved sample is vaporised, i.e. the dispersion of chemical compounds within water when released through a plant's stomata (structures that allow the exchange of gas and transpiration).

Wicking: The action by which water moves upward within a capillary cone.

WMS: WMS is Water Management Solutions. These consist of products and systems that help manage water effectively and sustainably – from a planted drainage system using tree roots and geocellular products, to a large attenuation Ridgistorm-XL tank system to manage extreme weather events within residential developments.

WRAS: The purpose of WRAS (Water Regulations Advisory Scheme) is to contribute to the protection of public health by preventing contamination of public water supplies and encouraging the efficient use of water by promoting and facilitating compliance with the Water Supply (Water Fittings) Regulations and Byelaws in Scotland.

6.1 Sources

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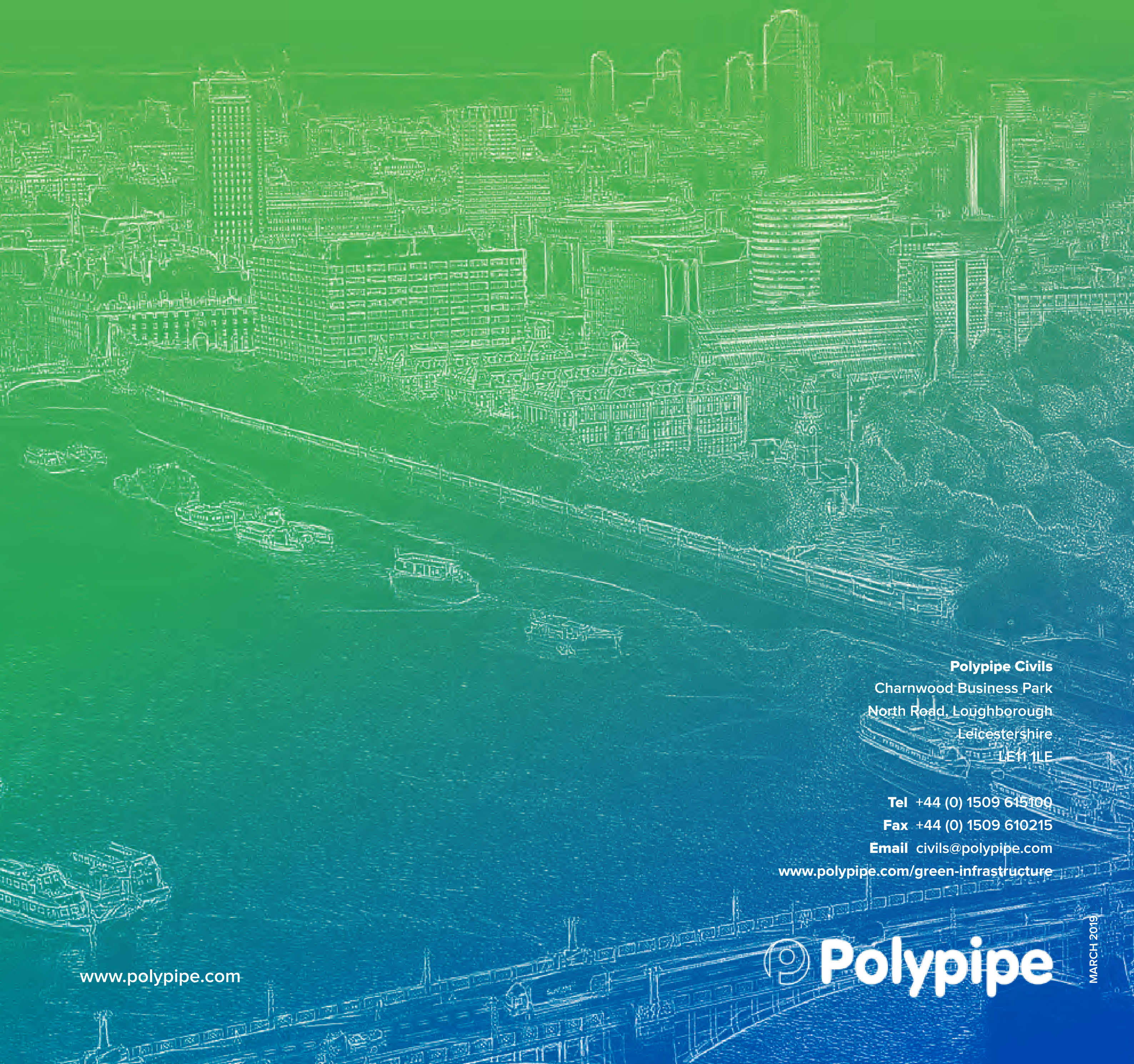

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