Gloucestershire County Council

Gloucestershire SuDS Design & Maintenance Guide

November 2015

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01 Introducing the guide

01 Introducing the guide

1.1. Purpose of the document

In a written statement to Parliament, Eric Pickles[1] announced that the required changes to the planning system will take effect from the 6th April 2015. The statement says that under the new arrangements, "in considering planning applications, local planning authorities should consult the relevant lead local flood authority on the management of surface water; satisfy themselves that the proposed minimum standards of operation are appropriate and ensure through the use of planning conditions or planning obligations that there are clear arrangements in place for ongoing maintenance over the lifetime of the development. The sustainable drainage system should be designed to ensure that the maintenance and operation requirements are economically proportionate. To protect the public whilst avoiding excessive burdens on business, this policy will apply to all developments of 10 homes or more and to major commercial development"

In addition, from 15th April 2015 the Lead Local Flood Authority will be included as a statutory consultee on major planning applications with surface water drainage implications to ensure technical advice is available to local planning authorities.

For the county of Gloucestershire, approvals for SuDS will be granted through planning applications submitted to the District Council or County Councils.

This guide is intended for use by developers, designers, engineers and other professionals who are seeking guidance on the County Council's requirements for the design of Sustainable Drainage Systems (SuDS) in Gloucestershire. It provides information for those that are involved with planning, design, and construction of new developments, including homes, buildings and roads, whereby new drainage infrastructure considers the use of SuDS for the sites.

It sets out the planning, design and maintenance requirements for delivery of attractive and high quality SuDS schemes that would offer multiple benefits to the environment and communities and will ensure a smooth and satisfactory SuDS approval process.

Adherence to the principles set down in this guide will normally ensure that SuDS schemes are suitable for submission for approval by the relevant planning authority in Gloucestershire and that they are in line with the requirements of the Lead Local Flood Authority (Gloucestershire County Council).

It is important that the Planning Authority is contacted at an early stage in development so that pre-application talks can take place. This document provides a guide on what is expected, including details of hydrological requirement, but detailed discussion of the proposal should take place during the design phase of the scheme, if an application is to be successfully approved.

SuDS philosophy and concepts are set in National Standards for SuDS (2015). Design of SuDS to follow that concept is detailed in The SuDS Manual (CIRIA C697). This guide should be seen as a complementing source document and so users of this guide should familiarise themselves with National Standards for SuDS and The SuDS Manual and incorporate advice from all three documents into their SuDS proposals.

[1] Written Statement to Parliament – Sustainable drainage systems, 18th December 2014 (https://www.gov.uk/government/speeches/sustainable-drainage-systems)

02 Legislation

02 Legislation

2.1. The Flood & Water Management Act 2010

The Flood and Water Management Act 2010 (the Act) was introduced to address the concerns and recommendations raised in the Pitt Report following the 2007 floods. The document is available to download from the UK legislation website (http://www.legislation.gov.uk).

The Act requires developers to include sustainable drainage techniques where practicable in all new developments and ensure SuDS are built to a standard that will reduce flood risk and improve water quality. It also amends Section 106 of the Water Industry Act 1991 to make the right to connect surface water run-off to public sewers conditional on meeting the new standards.

Schedule 3 to the Act outlined a proposal for Gloucestershire County Council to be a SuDS Approving Body (SAB), responsible for approving all surface water drainage systems for new developments in line with a set of National Standards set out by Government as well as any specific local standards as defined in this guidance document.

Following extensive consultation the Government has confirmed an alternative approach to the delivery of Sustainable Drainage Systems through changes to the planning system rather than through the approval regime originally proposed under Schedule 3 of the Flood and Water Management Act 2010.

The Government has introduced the Lead Local Flood Authority (LLFA) as a statutory consultee on major planning applications with surface water drainage implications to ensure technical advice is available to local planning authorities.

Gloucestershire County Council as an Upper-tier local is designated as Lead Local Flood Authority and has responsibility for managing local flood risk from surface water, groundwater and ordinary watercourses and also where there is an interaction between these sources and main rivers or the sea. As LLFA, Gloucestershire have a duty to:

- Cooperate with other Risk Management Authorities
- Develop a Strategy for managing local flood risk in Gloucestershire, is available at http://www.gloucestershire.gov.uk/CHttpHandler.ashx?id=61257&p=0
- Establish and maintain a register of flood risk management assets
- Investigate flooding incidents
- Issue Land Drainage Consents for works on ordinary watercourses
- Designate assets which provide a flood risk management function

Gloucestershire County Council promotes the use of Sustainable Urban Drainage Systems (SuDS) which help to reduce surface water runoff, mitigate flood risk, improve water quality and encourage biodiversity.

The European Water Framework Directive requires that surface water discharges are managed so that their impact on the receiving environment is mitigated. The objective is to protect the aquatic environment and control pollution from diffuse sources such as urban drainage – a key aspect that effectively precludes use of the traditional approach to drainage.

2.2. Water Industry Act 1991

Section 106(A) in the Water Industry Act 1991 (inserted by paragraph 16 in Schedule 3 to the Flood and Water Management Act 2010) prohibits a SuDS from being connected to the public surface water sewer or combined sewer unless the SuDS (including the manner of connection) has been approved.

This modifies the normal right under section 106 in the Water Industry Act 1991 to connect both foul and surface water drainage to the public sewer system. Instead, infiltration to the ground and connection to the watercourses should be first investigated, and if not possible, only then a connection to the public sewer will be allowed. Furthermore, it is expected that the National SuDS Standards will prohibit discharge of surface water to a foul sewer.

2.3. National Policy Guidance

2.3.1. National Planning Policy Framework

The National Planning Policy Framework (NPPF) came into force in March 2012. It applies to England and replaces the numerous 'Planning Policy Statements' and other policy documents. The NPPF sets out the Government's spatial planning policy on development and flood risk. It aims to ensure that flood risk is taken into account by all relevant statutory bodies from regional to local authority planning departments to avoid inappropriate development in areas at risk of flooding and to direct development away from areas of highest risk. It must be taken into account in the preparation of local and neighbourhood plans, and is a material consideration in planning decisions.

One of its core principles is to secure high quality design and seek a good standard of amenity, whilst contributing to conserving and enhancing the natural environment and reducing pollution. These principles align with the aims of SuDS.

The NPPF also requires local plans to use opportunities offered by new development to reduce the causes and impacts of flooding. Furthermore, when determining planning applications, local planning authorities should ensure flood risk is not increased elsewhere.

The technical guidance document to the NPPF states that the appropriate application of SuDS in all Flood Zones must be considered and where appropriate, utilised to "control surface water run-off close to where it falls and mimic natural drainage as closely as possible".

It is important that any development does not increase the flood and pollution risks to the environment. Consideration of this must be given throughout the design process. The documents are available to download from the Department for Communities and Local Government website (http://www.communities.gov.uk).

Local Authorities in England will only consider development in flood risk areas as appropriate where informed by a site-specific FRA, based upon the Environment Agency's Standing Advice on flood risk.

The FRA should identify and assess the risks of all forms of flooding to and from the development and demonstrate how flood risks will be managed so that the development remains safe through its lifetime, taking climate change into account.

For flood risks in general, there is a hierarchy that should be applied for flood risk management, with avoidance or prevention being the preferred first measure to reduce flood risk. The following list below shows the flood risk management hierarchy:

Table 2-1 - The flood risk management hierarchy

1	Assess	Undertake studies to collect data at the appropriate scale and level of detail to understand what the flood risk is
2	Avoidance/ Prevention	Allocate development to areas of least risk and apportion development types vulnerable to the impact of flooding to areas of least flood risk
3	Substitution	Substitute less vulnerable development types for those compatible with the degree of flood risk
4	Control	Implement flood risk management measures to reduce the impact of new development on flood frequency and use appropriate design
5	Mitigation	Implement measures to mitigate residual risks

The NPPF assigns the level of risk depending on the annual probability of fluvial flooding occurring as follows, based on Environmental Agency derived flood maps:

- Flood Zone 1: Low Probability (<0.1% AEP fluvial / sea flooding);
- Flood Zone 2: Medium Probability (0.1-1.0% AEP fluvial / 0.5-0.1% AEP sea flooding);
- Flood Zone 3a: High Probability (>1% AEP fluvial / >0.5% AEP sea flooding); and,
- Flood Zone 3b: Functional Floodplain (>5% AEP or designed to flood in 0.1% event).

Where new development is, exceptionally, necessary in high risk flood areas, the NPPF aims to make it safe, without increasing flood risk elsewhere and, where possible, reducing flood risk overall.

Development should be directed as far as is practicable towards Flood Zone 1 areas to avoid fluvial flood risks wherever this is possible.

All development greater than 1 hectare, and any development in Flood Zones 2 and 3 or critical drainage areas, require a FRA to address design issues related to the control of surface water runoff and climate change, as well as considering any other potential sources of flood risk for the development site.
A flood risk assessment (FRA) should consider all types of flooding to satisfy the following three key objectives:

- to assess flood risk to the proposed development from all sources of flooding and to demonstrate that any residual risks to the development and its users would be acceptable;
- to assess the potential impact of the proposed development on flood risk elsewhere and to demonstrate that the development would not increase flood risk elsewhere; and,
- to satisfy the requirements of the NPPF.

Flood risk should be considered alongside other spatial planning issues such as transport, housing, economic growth, natural resources, regeneration, biodiversity, the historic environment and the management of other hazards.

CIRIA C624 provides guidance on the implementation and good practice in assessing flood risks through the development process. The aim of C624 is to promote developments that are sustainable with regard to flood risk. The document recommends that a FRA should be undertaken in phases so that the type of development corresponds with the detail required.

2.3.2. Non-Statutory Technical Guidance

The National Standards detail design criteria for SuDS such that:

- Flood risk from the site drainage system shall be limited to the 1 in 30 year event
- Flood risk to people and property is controlled to the 1 in 100 year event taking into account the impact of climate change
- Flood risk from overland flows off adjacent land shall be limited to 1 in 100 years taking into account the impact on climate change

The SuDS design shall also consider the risk of exceedance events and ensure that water can be controlled and safely passed through the site.
The Standards detail criteria for water quality, amenity and biodiversity and give recommendations for construction, operation and maintenance of future SuDS.

2.3.3. Building Regulations

Part H of the Building Regulations states the hierarchy for surface water disposal, which encourages a SuDS approach.

The hierarchy is surface water disposal using SuDS, which encourages infiltration, followed by discharge to a watercourse and finally discharge to a surface water or combined sewer. Rainwater harvesting should be encouraged wherever practicable.

The document is available to download from the Planning Portal website which is delivered by the Department of Communities and Local Government (http://www.planningportal.gov.uk).

2.3.4. Green Infrastructure Guidance

Natural England's "Green Infrastructure Guidance", states the importance of green infrastructure and the drivers for it, as well as the key environmental functions and the socio-economic benefits of the green infrastructure approach.

The document is available for download from the Natural England website. (http://www.naturalengland.org.uk).

The Gloucestershire Local Nature Partnership (LNP) has a Mission Statement "To improve the prospects for Gloucestershire's natural environment while demonstrating its vital role in our health & well-being, its significant contribution to a thriving economy and to a better quality of life for all ". The Strategic Framework for Green Infrastructure in Gloucestershire 2014 can be downloaded at http://www.gloucestershirebiodiversity.net/publications/index.php.

The Gloucester, Cheltenham and Tewkesbury Joint Green Infrastructure Strategy recognises that SuDS offer significant opportunities to augment the existing Green Infrastructure asset. The strategy recommends Guidance on SuDS as a means of delivering green infrastructure benefits as well as drainage solutions.

The document is available for download from the Joint Core Strategy website. (http://www.gct-jcs.org/Documents/EvidenceBase/Green-Infrastructure-Strategy-June-2014.pdf).

2.4. Local Policy Guidance

This guidance document has been written to assist developers in the design of SuDS at each stage of the planning process. Adherence to this guidance should result in SuDS being approved. This will avoid the abortive costs and delays associated with having to redesign development schemes and potentially repeat stages in the planning process. In addition, properly planned SuDS which are fully integrated into a development should make the developments more attractive to investors.
Developers should seek to comply with the policies given in Section 2.4.2 when designing SuDS as part of a wider development.

2.4.1. Strategic Flood Risk Assessment

The Gloucestershire Strategic Flood Risk Assessment (SFRA 2008) has been prepared to support the application of the Sequential Test as outlined in the NPPF, and to provide information and advice in relation to land allocations and development control.

The individual district Level SFRAs for Cheltenham, Cotswold, Forest of Dean, Gloucester City, Stroud and Tewkesbury can be found at: http://www.gloucestershire.gov.uk/extra/SFRA.

The SFRAs have assessed all forms of flood risk: fluvial (rivers), surface water, groundwater, sewers and impounded water bodies (reservoirs and canals), both now and in the future given the likely impacts of climate change. The SFRA includes maps showing areas at risk from flooding.

The Environment Agency constantly review and update their flood zone maps, meaning that sometimes the maps contained in the SFRA are out of date. We consider that EA maps take priority over those included in our SFRA, and that the revised SFRA takes precedence over the original SFRA document.

2.4.2. Local Planning Policies

The Local plan for each district is the key planning policy document which guides decisions on the use of land in each district. Planning policies for each district relating to SuDS are as follows:

Cotswold Local Plan (2015,emerging)
No specific policies related to SuDS yet available in emerging local plan.

Forest of Dean Core Strategy (2012, adopted)
Policy CSP1 Design, environmental protection and enhancement (strategic objective: providing quality environments) states "The design and construction of new development must take into account important characteristics of the environment and conserve, preserve or otherwise respect them in a manner that maintains or enhances their contribution to the environment, including their wider context". The policy states that development proposals should include "any mitigation that may be necessary to ensure the development is safe and flood risk is not increased elsewhere".
Policy CSP2 Climate Change Adaptation (Strategic objective: thriving sustainable communities) states that "Sustainable Drainage Systems (SuDS) and measures to reduce or avoid water contamination and safeguard ground water supply should be incorporated into all development unless it can be demonstrated that this is not appropriate in a specific location".

http://www.fdean.gov.uk/media/Assets/ForwardPlan/documents/Core%20Strategy%20Adopted%20Version%2023th%20February%202012/Core_Strategy_Adopted_Version.pdf

Gloucester/Tewkesbury / Cheltenham – Joint Core Strategy (Emerging Local Plan (2015)
Policy INF3: Flood Risk Management requires "new development to incorporate suitable Sustainable Drainage Systems (SuDS) where appropriate in the view of the local authority to manage surface water drainage: to avoid any increase in discharge into the public sewer system; to ensure that flood risk is not increased on-site or elsewhere; and to protect the quality of the receiving watercourse and groundwater. Where possible, the authorities will promote

the retrofitting of SuDS and encourage development proposals to reduce the overall flood risk through the design and layout of schemes which enhance natural forms of drainage. Developers will be required to fully fund such mitigation measures for the expected lifetime of the development including adequate provision for on-going maintenance".

http://www.gct-jcs.org/Documents/Publications/Submission/JCS-Submission-Version-November-2014a.pdf

Stroud Local Plan (2014, emerging)
Core Policy CP5 - Environmental development principles for strategic sites (Principles for the siting, design and construction of strategic development) states "Applications for all strategic sites (both residential and non-residential) will be required to provide a statement demonstrating how sustainable construction principles have been incorporated. This should address demolition, construction and long term management. This will be expected to show how the proposal maximises its contribution towards .... Incorporating Sustainable Drainage Systems".

Site Allocations Policy SA1 Stroud Valleys/ SA3 North East of CAM/ SA4 Hunts Grove Extension/SA5 Sharpness Docks state that "Development briefs, to be approved by the District Council, will detail the way in which the land uses and infrastructure will be developed in an integrated and co-ordinated manner" including "The acceptable management and disposal of surface water, including sustainable drainage systems (SuDS) to meet the requirements of the Environment Agency".

Delivery Policy EI4 - Development on existing employment sites in the countryside states that "Proposals will be expected to include measures to secure environmental improvements such as landscaping, enhancing biodiversity and incorporating SuDS".

Core Policy CP14 - High Quality Sustainable Development states that "No unacceptable levels of air, noise, water, light or soil pollution or exposure to unacceptable risk from existing or potential sources of pollution. Improvements to soil and water quality will be sought through the remediation of land contamination, the provision of SuDS and the inclusion of measures to help water bodies to meet good ecological status" and "No increased risk of flooding on or off the site, and inclusion of measures to reduce the causes and impacts of flooding as a consequence of that development".

Delivery Policy ES4 - Water resources, quality and flood risk states that "New developments will be required to incorporate appropriate Sustainable Drainage Measures (SuDS). This should be informed by specific catchment and ground characteristics, and will require the early consideration of a wide range of issues relating to the management, long term adoption and maintenance of SuDS".

http://www.stroud.gov.uk/info/plan_strat/Submission_Draft.pdf

2.4.3. Supplementary Planning Documents

Cheltenham Sustainable Drainage Systems SPG (2003)
The Supplementary Planning Guidance relates to policy UI 117 in the Cheltenham Borough Local Plan Second Review Revised Deposit Draft (2004) and will be superseded by policies in the emerging Joint Core Strategy.
http://www.cheltenham.gov.uk/downloads/file/3237/sustainable_drainage_systems_-_2003

Tewkesbury Flood and Water Management SPD (2014)
The supplementary planning document outlines the key flood and water management objectives of Tewkesbury Borough Council, including:

- To ensure that new development does not increase the risk of flooding either on a site or cumulatively elsewhere; and to seek betterment, where possible.
- To require the inclusion of Sustainable Drainage Systems (SuDS) within new developments, which mimic natural drainage as closely as possible (e.g. permeable paving, planted roofs, filter drains, swales and ponds) and provision for their long-term maintenance, in order to mitigate the risk of flooding.
- To encourage on-site storage capacity for surface water attenuation for storm events up to the 1% probability event (1 in 100 years) including allowance for climate change. http://tewkesbury.gov.uk/CHttpHandler.ashx?id=3344&p=0

Gloucester City Sustainable Drainage – A Design and Adoption Guide (2013)

This Design and Adoption Guide sets out the requirements and design process for SuDS using examples that show how SuDS features can enhance the landscape. This Design and Adoption Guide also develops an adoption process for SuDS features by Gloucester City Council where they meet the adoption criteria agreed by the Council.

http://www.gloucester.gov.uk/resident/Documents/Planning%20and%20Building%20Control/SUDS%20for%20GCC%20FINAL%20July%202013%20Document.pdf#search=sustainable%20drainage

03 Context for SuDS in Gloucestershire

03 Context for SuDS in Gloucestershire

3.1. Context for SuDs

This section introduces the design considerations for the county of Gloucestershire due to the terrain, rainfall, geology, historic, built and natural environment, nature conservation and flood risk. Further information is provided in the subsequent sections.

Gloucestershire borders Herefordshire, Worcestershire, Warwickshire, Oxfordshire, Wiltshire, South Gloucestershire and Somerset and covers an area of 3,150 km^2.

The county contains the elevated Forest of Dean in the west and Cotswold hills in the east, and is split by the low Severn Vale floodplain through the centre. The Thames runs to the east, with the Wye in the west, and countless tributaries drain to these three main watercourses.

The county town of Gloucester is located on the River Severn, with other significant urban areas being Cheltenham, Cirencester, Stroud and Tewkesbury.

The maximum elevation in Gloucestershire is 330m above sea level, at Cleeve Hill in the Cotswolds.

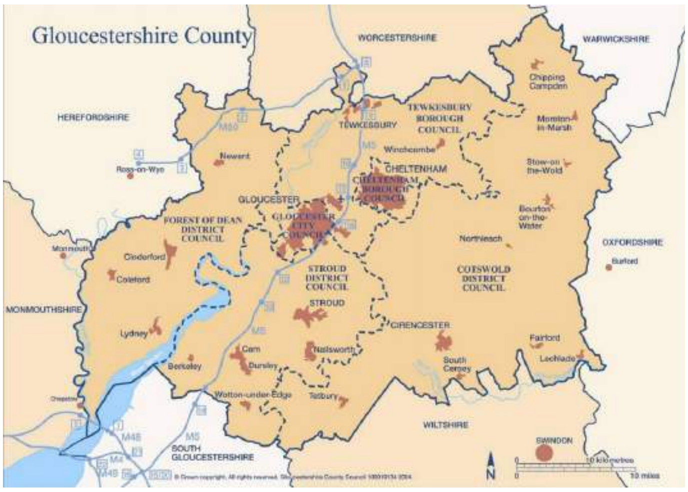


Figure 3-1 - Gloucestershire and surrounding areas
(Source http://nora.nerc.ac.uk/20840/1/SuDS%20case%20study_corporate_Dec12v2.pdf)

3.2. Geology

3.2.1. Relevant British Geological Survey datasets

The British Geological Survey (BGS) have produced a series of maps which provide information on the potential suitability of ground to accept infiltration from SuDS. More information is available from their website . The dataset covers the whole of Gloucestershire and provides a useful starting point to understand the potential for different types of SuDS. Table 4 of the BGS document "Suitability of the subsurface for infiltration SuDS in Great Britain" indicates that in Gloucestershire:

- 31% of the area is compatible for infiltration SuDS (suitable for free-draining SuDS)
- 10% is probably compatible for infiltration SuDS (system design may be influenced by ground conditions)
- 40% of the area has opportunities for bespoke infiltration SuDS (design likely to be highly influenced by ground conditions)
- Only 20% of the area has very significant constraints indicated to limiting infiltrations SuDS

These values are indicative of the general suitability of Gloucestershire for infiltration SuDS. They indicate that it is more likely than not that an infiltrating SuDS design should be possible. This is therefore what will be expected of submissions, unless good justification can be made against such a scheme. The BGS dataset is not sufficient to base a scheme design on, however, and consequently an infiltration test should be undertaken on site prior to submitting a planning application.

The BGS also have other datasets which may be of use in guiding SuDS design, such as borehole logs and geology maps.

3.2.2. Forest of Dean geology

Most of the Forest of Dean area may be suitable for infiltration SuDS. Sandstones are porous, meaning that water can fill the gaps between particles. Therefore it is likely that the area to the north of the Forest of Dean containing Redmarley D'Abitot should facilitate the construction of SuDS requiring infiltration. Likewise the strip of land in the centre of the area running north to south around Littledean and Mitcheldean. Mudstones can vary significantly in their capacity to allow infiltration, and therefore areas indicated as mudstone should have infiltration tests undertaken as a priority to understand the local potential for infiltration SuDS.

[1] BGS website http://www.bgs.ac.uk/products/hydrogeology/infiltrationSuds.html [Accessed: 12 February 2015]

[2] BGS website, http://nora.nerc.ac.uk/20840/1/Suds%20case%20study_corporate_Dec12v2.pdf [Accessed 12th February 2015]

Limestone areas around and to the south of Coleford provide excellent infiltration opportunities for features such as swales, although consideration needs to be given to protecting any aquifers in these area from contamination, especially where the limestone area is used to provide drinking water.

3.2.3. Cotswolds geology

The Oolitic geology of the Cotswolds offers low/medium infiltration potential, and covers much of the central area of the Cotswolds. Clays can be found around Down Ampey and Meysey Hampton, in an area otherwise consisting of alluvium, fluvial and glacial deposits. Infiltration testing at these locations will be required to determine whether the site sits on geology that enables infiltration or not. Similarly the geology around Fairford is complex and will require identification on site. Kempsford and Lechlade-on-Thames lend themselves well to infiltration SuDS. Areas of the Cotswolds can also be affected by a high water table, which should be investigated through infiltration testing

To the north of the Thames is a series of four terraces consisting of Oolitic limestone gravels to a depth of 6m. These offer very good potential for infiltration SuDS.

3.2.4. Severn Vale geology

The eastern part of Gloucestershire is underlain by sandstones and Mercia Mudstone. There are widespread superficial deposits consisting of alluvium deposits on the Severn floodplain and terraces. The Cheltenham-Gloucester area consists of a well-draining, light soil which is a good example of an isolated deposit of a limestone gravel fan. Isolated pockets of this soil exist across the Vale area. These areas are good for SuDS infiltration schemes. Sporadic clay formations generally have limited infiltration potential, meaning that in these locations solutions providing attenuation capacity should be targeted.

The presence of a clay layer can mean that features such as ponds are cheaper to install as the clay can act as a liner to the feature.

3.3. Aquifers

Aquifers are used to provide drinking water and water for irrigation in some parts of the country. Groundwater protection zones are in place to protect aquifers which provide water for drinking from pollution. In groundwater protection zones where the ground is contaminated, consideration will need to be given to using biomembranes and liners to stop any contaminants from passing through SuDS into the aquifer. Figure 3-2 shows an example of the data available from the Environment Agency "What's in your backyard" website[4] , showing the locations of groundwater protection zones. More information on what is deemed appropriate for each type of SuDS can be found in Section 9.

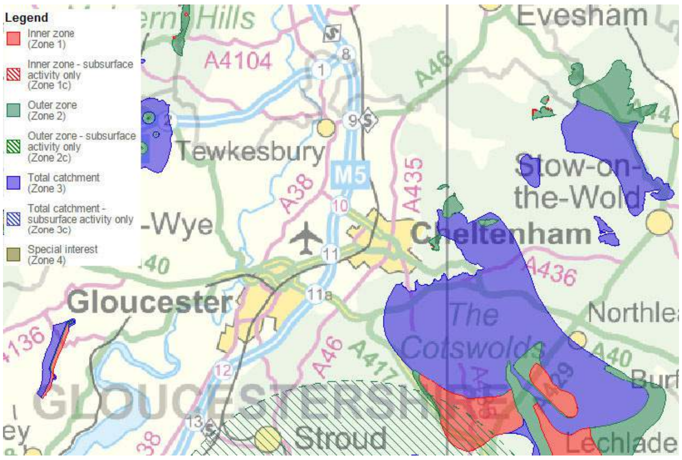


Figure 3-2 - Groundwater Source Protection Zones in Gloucestershire

(Source: Environment Agency Website)

3.4. Climate

Gloucestershire has a temperate climate which is generally wetter and milder than the rest of the country. It has a standard average annual rainfall (SAAR) of between 790mm in the north, and 860mm in the south.

The volume of rainfall has a direct impact on how your SuDS scheme needs to be set out and designed.

It is now recognised that climate change and global warming is a reality and that whilst climate is subject to natural fluctuations, the recent acceleration of temperature is due to human activities, mainly the burning of fossil fuels. This releases large amounts of CO_2, which is a key greenhouse gas. Projections show that the smallest likely effect in the UK by 2030 (under a 'least emissions scenario') will be a mean summer temperature rise of 0.7 to 2.7 degrees C. Winters in Gloucestershire are likely to be wetter and summers drier; extreme weather events will be more common. Locally, symptoms will include damage to infrastructure and increased strain on services such as health provision.

[4] Taken from the Environment Agency website http://apps.environment-agency.gov.uk/wiyby/default.aspx [Accessed 12th February 2015

3.5. Nature Conservation and biodiversity

Gloucestershire has many important habitats, rare and protected species and a wide diversity of animals and plants. This biodiversity is a consequence of the county's varied land form, geology, soils, habitats and built structures, which in turn have been influenced by farmers, estate owners, conservationists, developers and others.

The importance of Gloucestershire's biodiversity is recognised in that many areas of the county are covered by international, national and local nature conservation designations. It is vital that these natural aspects of the county are conserved and that any new developments take account of the flora and fauna in and around the site.

The Gloucestershire Nature Map (Figure 3-3) delineates landscape-scale blocks of land called Strategic Nature Areas which show where the characteristic habitats that typify the county can be expanded and linked to help wildlife survive in an uncertain future.

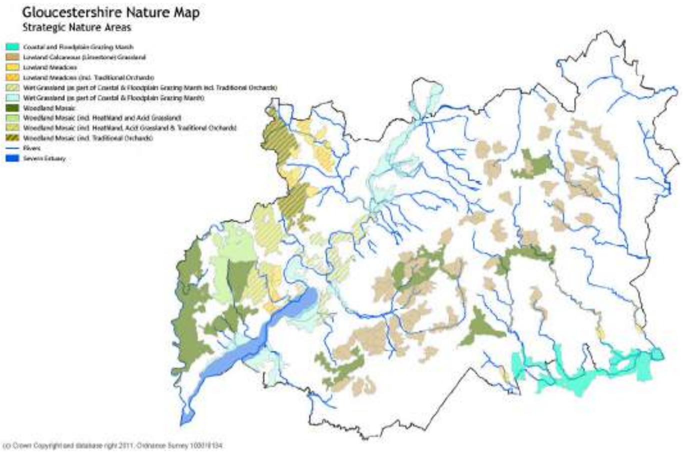


Figure 3-3 – Gloucestershire Nature Map

Guidance on applying the Gloucestershire Nature Map and other background information is available from Gloucestershire's Local Nature Partnership website[5].

3.6. Flood Risk

Gloucestershire has a long history of flooding from the main rivers and tributaries of the Severn, Wye and Thames catchments. In summer 2007

Gloucestershire experienced one of the most significant flood incidents seen in the UK. Following a relatively dry spring the summer was one of the wettest on record. Heavy rainfall at the end of June led to flooding in some areas in Gloucestershire, both from surface water overloading the drainage systems and very high water levels in rivers and brooks. Heavier rain fell in July and on the 20th July the equivalent of two months' rain fell in 14 hours. Climate change projections imply that rain storms may become more intense in the future. Managing runoff in urban areas is essential to ensure future development is sustainable.

A SFRA for Gloucestershire has been produced and is available from the Gloucestershire County Council website[6]. This assesses the risk of flooding from a variety of sources, including the risk posed by surface water flooding.

The SFRA identifies general areas considered at higher risk of flooding. These are shown on Figure 3-4 with areas at higher risk of flooding from all sources shown highlighted in red, whilst those with moderate risk of flooding from all sources are shown in orange.

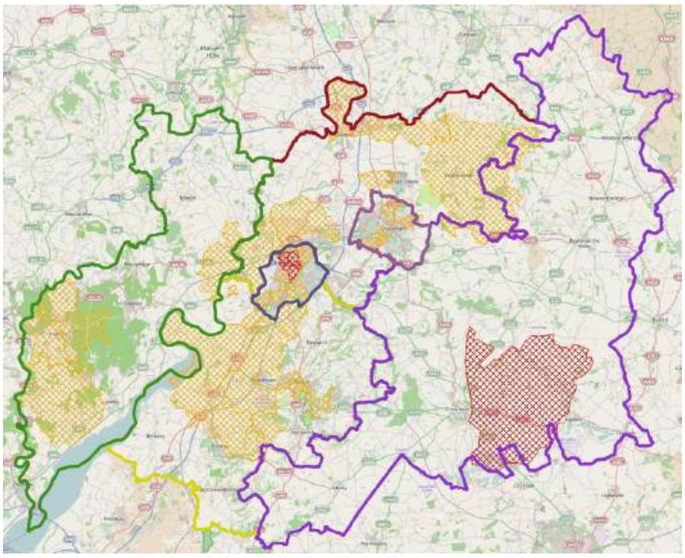


Figure 3-4 - Flood risk identified by SFRA

[5] Gloucestershire Local Nature Partnership [Online]. Available from: http://gloucestershirebiodiversity.net/index.php. [Accessed 23rd January 2015]

[6] Gloucestershire County Council website [Online]. Available from http://www.gloucestershire.gov.uk/extra/SFRA. [Accessed 26th January 2015]

3.6.1. Gloucester City: Surface Water Flood Risk

The Level 2 strategic flood risk assessment identifies two main sources of flood risk to Gloucester City. The first is flooding from the River Severn coming out of bank and causing tributaries to back up, and the second is that arising from integrated flood risk from constrained urban watercourses.

Surface water flood risk mapping indicated a risk at a number of locations across the City, with particular risk associated with areas adjacent to Sud Brook. Intermediate surface water flood risk maps are available in Appendix A of the Level 2 SFRA. The Level 1 SFRA also provides the following insight into surface water flooding in each of the districts:

3.6.2. Forest of Dean District Council: Surface Water Flood Risk

Flooding from surface water is a problem within the District, with the geology and topography contributing to increased likelihood of surface water flooding.

The upper reaches of river catchments within the District, although underlain by permeable limestone and sandstone, are often steep, promoting rapid surface runoff which can lead to localised flooding. In addition, the clays and mudstones found within the Severn Valley lie close to the groundwater table for much of the year and are frequently saturated.

Areas with an abundance of impervious surfaces are also at risk of surface water flooding, especially when local intense rainstorms occur. Surface water flooding associated with poor urban drainage and backing up within urban drainage systems under high river flows affects Coleford and Lydney in particular.

3.6.3. Tewkesbury Borough Council: Surface Water Flood Risk

Flooding from surface water is a problem within the Borough, with the largely impermeable geology and gentle topography of the Borough contributing to increased likelihood of surface water flooding.

Areas with an abundance of impervious surfaces means these areas are also at risk of surface water flooding, especially when local intense rainstorms occur. High water levels in the River Severn can also prevent minor watercourses draining.

3.6.4. Cheltenham Borough Council: Surface Water Flood Risk

Flooding from surface water is a problem within the Borough, particularly in the town due to abundance of impermeable surfaces. In the past the River Chelt was diverted from its natural course to higher ground in order to feed the great mills. The original river valley was subsequently developed with housing estates, public buildings and industrial development. Consequently, when intense rainfall events occur, runoff follows natural topography and accumulates at the valley bottom, which can flood areas of the town centre.

The drainage system in the Borough is known to be quite old and there is potential for the drainage systems to overload and exacerbate surface water flooding.

3.6.5. Cotswold District Council: Surface Water Flood Risk

It is evident that surface water flooding is a problem throughout the District, with reported incidents referring to runoff from hills and drains being unable to cope with storm water.

During the summer 2007 floods exceptional rainfall was experienced at RAF Fairford resulting in flooding to the airfield and surrounding villages of Whelford, Dunfield and Marston Meysey.

3.6.6. Stroud District Council: Surface Water Flood Risk

Flooding from surface water is a problem within the District particularly around Stroud. This is due to the combination of steep catchments, combined urban drainage networks, and older style properties.

Surface water flooding has been identified along the River Frome catchment, mainly due to the steep topography.

04 Principles of SuDS

04 Principles of SuDS

4.1. General design principles

The National Standards for SuDS design[7] describes the main principles and standards expected in Gloucestershire. Furthermore, all SuDS should be designed in accordance with CIRIA C697, its update manuals (Reports RP992/15 to RP992/31) and CIRIA C698 guidance.

For the success of SuDS, it is important for the design to satisfy the Sustainable Drainage Triangle (Figure 4-1) taking account of water quality, water quantity and amenity/ biodiversity. By considering this set of conditions, SuDS design should attempt to maximise the potential to provide solutions which are:

- water sensitive (i.e. water management close to the natural water cycle and water quality treatment through natural processes inherent in the system);
- functional and easy to maintain;
- aesthetically pleasing (i.e. integrate with the landscape);
- usable and acceptable by local inhabitants; and
- wildlife friendly.

Successful SuDS designs are likely to sit in the centre of the Venn diagram, positively impacting water quantity and quality whilst providing amenity value. When quantity, quality and amenity have been addressed in the design, this will result in a sustainable system design.

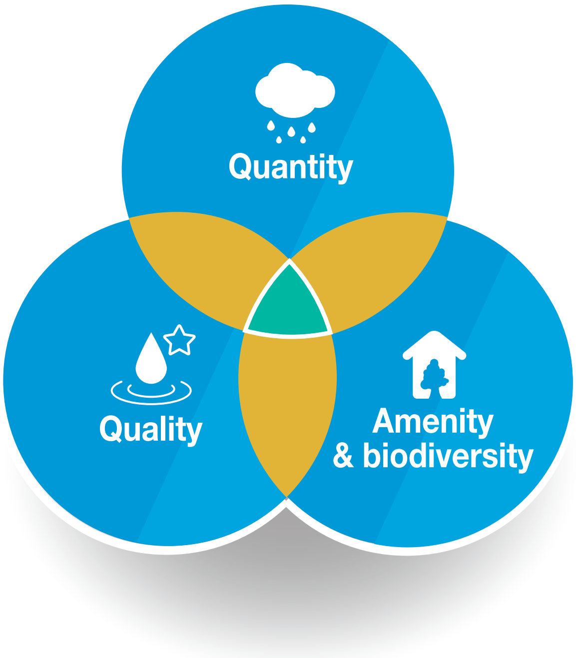


Figure 4-1 - SuDS triangle

[7] Defra (January 2014) Draft National Standards for Sustainable Drainage

4.1.1. SuDS Management Train

The SuDS management train is often known as the SuDS treatment train. The principle is that a series of different SuDS techniques can be employed to change the water quality and flow characteristics of the runoff. This is critical to SuDS design. A variety of SuDS types allows for different treatment mechanisms to impact water quality, as well as for different attenuation locations and volumes to be incorporated into a design. The management train also allows for source, site and regional controls to be incorporated, controlling runoff at a variety of scales.

Prevention measures at source provide the starting point, with control techniques used to manage water as close as possible to where the rain hits impermeable surfaces. Source control often provides protection against siltation of downstream elements. Site controls within or just outside the development then provide attenuation and polishing of water quality as well as amenity value. In combination, source and site controls therefore meet the requirements of the SuDS triangle to produce a high quality, sustainable design.

4.1.2. Quantity

SuDS should use various methods and features to manage the quantity of surface water runoff from the development site, and protect people and property from surface water flooding.

Flows, volumes and the frequency of runoff should be controlled such as it resembles the natural water cycle; matching the natural drainage routes, infiltration rates and discharges as far as possible. The Non Statutory Technical Standards specify the frequency, rate and volume of the runoff from the development site. This will have to be no greater than the equivalent greenfield conditions (with allowance for climate change). See Section 5.2.

When designing SuDS, it is also important to consider the receiving watercourses and drainage systems, and overland flows to and from adjacent land. It must be demonstrated that the proposed development will mitigate flood risk from the existing adjacent land (if any) and will not increase flood risk at any other points upstream or downstream of the development. The Environment Agency's maps indicating areas prone to surface water flooding should be considered and mitigation measures included in the design. Can be found at http://watermaps.environment-agency.gov.uk/wiyby/wiyby.aspx?topic=ufmfsw#x=357683&y=355134&scale=2

The Non-Statutory Technical Standards require that SuDS should be specifically designed so that:

- In a 1 in 30 year rainfall event, there will be no flooding anywhere on the site where the SuDS is built. The SuDS will deal effectively with the water;
- In a 1 in 100 year rainfall event, there will be no flooding in any part of any building on the site, in any part of any utility plant on the site, or on any neighbouring land (caused by the surface water from the site).
- For any rainfall event above 100 year, the drainage design should demonstrate how exceptional flows generated within or from outside the site will be managed including overland flow routes, protection of buildings to prevent entry of water, and protection of major access routes including access to institutional buildings.

For full design criteria refer to the National Standards and SuDS Manual CIRIA C697 until the formal update is produced.

4.1.3. Quality

To protect the groundwater and receiving watercourses, it is essential to capture, control and treat pollution carried by the site surface water runoff as close as possible to the source. Passing surface water flows through a series of different types of SuDS (the process known as 'SuDS treatment train') provides a high level of treatment. Each type of SuDS presents at least one level of treatment. For example, oils and hydrocarbons can be trapped in permeable pavements and broken down by micro-organisms. The treatment time is typically between 1 and 3 months.

Using the SuDS treatment train concept will also help mimic the natural drainage regime of an area, thus minimizing impact on receiving watercourses.

Further guidance on the treatment train process is available in CIRIA C697 SuDS Manual.

Prevention or good housekeeping is essential as good site design can manage how pollutants can get in contact with surface water runoff. Following prevention, here are some ways in which the 'SuDS treatment train' approach could be applied in order to achieve good water quality:

- Source control: surface water runoff is controlled through one type of SuDS at or close to the source in order to control flow and volumes and intercept silt and prevent pollution. This initial treatment often provides adequately clean water for amenity and biodiversity within development especially in residential areas;
- Site control: after source control, runoff flows to another type of SuDS within or just outside of the development where it is stored and undergoes polishing treatment in an amenity SuDS feature.
- Regional control: Sometimes there is a need to provide another level of treatment or storage space in a larger "downstream" SuDS features (e.g. ponds, wetlands e.g. Figure 4-2) that will collect run-off from a site or several site beyond the development boundary. It happens in situation where there is a need for large attenuation of surface water or additional level of treatment in order to meet design requirement for pollution control.

Figure 4-2 - Site layout with pond treatment train to address water quality issues

The number of treatment stages required is defined in The SuDS manual (CIRIA C697) and varies with the environmental sensitivity of the receiving watercourse. One level of treatment can be considered as one SuDS feature. It is recommended that sites in excess of 2ha do not drain to a single SuDS component and instead a sub-area SuDS is designed – ensuring an effective treatment system.

4.1.4. Amenity and Biodiversity

Gloucestershire local authorities will require SUDs design to provide aesthetic and social benefits for the community along with opportunities for biodiversity enhancement.
Amenity benefits include:

- Attractive SuDS features adapted to the surrounding area (channels, rills, canals, cascades, ponds, e.g. Figure 4-3)
- Creation of places that are usable for recreation and/or nature conservation purposes.

As an overriding design principle, SuDS features should be kept at or near the surface and be integrated into the landscape. A high quality of engineering and landscape design must be applied throughout the SuDS design process: all SuDS should be adapted to the local conditions. The features should be safe and easy to maintain and the design must consider the possible need for future adaptation in the face of uncertain and changing conditions such as climate change or urban creep.

Aesthetic SuDS design will be better received by the public and is likely to increase the overall value of a development. Information and education about the SuDS features should be provided through signage to provide the public with an appreciation and understanding of their local SuDS. This will also provide information on the need for maintenance and any issues of safety. To minimise the health and safety risks, SuDS design should use gentle slopes sides and barrier planting to prevent easy access to the water along with shallow water depths and avoidance of sudden depth changes. See Chapter 12 for health and safety.

Benefits for wildlife will be achieved through the inherent water treatment and providing good ecological design. Ecological value can be achieved by mimicking the natural ecosystems, using native plants, by varying the habitat types and introducing diversity in the design.

The local principles for design described in Section 9 are those considered by Gloucestershire County Council as suitable for use in Gloucestershire to effectively reduce flood risk whilst improving public amenity and environment. This guidance supports the Non-Statutory Technical Standards and reinforces existing county standards for a consistent approach.

Figure 4-3: Amenity pond

05 The design of SuDS

05 The design of SuDS

5.1. The design of SuDS

All proposed SuDS shall be designed to either maintain or reduce the pre-development run-off rate to mimic a natural drainage response. Natural drainage typically allows rainfall to soak into the ground, where the geology allows. Otherwise, water will naturally follow low points in the topography to create a drainage network linking to streams and wetlands.

Where the natural surface is replaced, such as often occurs during development in urban areas, drainage will often connect to artificial pipe networks. These pipe networks are often much more efficient at moving water around, leading to rapid flow to where the pipe network discharges. In these circumstances the aim of SuDS is to reduce the rate of the flow into the pipe network to protect existing drainage systems and provide environmental benefits.

SuDS designs should take account of the original drainage paths determined predominantly by topography and geology as well as historic drainage systems such as culverts and ditches. The new SuDS system should identify flow paths across the site and identify the eventual discharge location of flows from the site.

This section outlines a methodology to establish the existing surface water discharge rate.

5.2. Point of Discharge

In order of preference, surface water should be discharged:

1. to the ground via infiltration;
2. to a surface water body including a watercourse; or
3. to public surface water sewer; or
4. to a combined sewer.

Evidence that the hierarchal approach has been applied must be provided before a SuDS application will be approved.

When considering the method of discharge the developer must establish the soil conditions and infiltration rates of the site at an early stage. Evidence of the site investigations (at locations and at an adequate depth of any proposed soakaway) must be provided to us. If no evidence is presented to secure that way of discharging surface water, then an alternative outfall should be identified in case forthcoming tests show inadequate infiltration.

If the site is not suitable for infiltration, discharge to a watercourse should be considered next. A suitable outfall location, discharge strategy, rates and consents (where required for some outfall structures) must be agreed with the relevant authorities.

- for discharges to Main Rivers, agreement is required from the Environment Agency; and
- for discharges into Ordinary Watercourses the agreement should be sought from Gloucestershire County Council.

The EA maps show where main rivers are designated.

If a discharge to the ground or watercourse is not feasible, a surface water connection to the public sewer should be considered as a last resort. Allowable discharge rates and connection points will need to be agreed with relevant sewerage undertaker (Severn Trent Water, Thames Water, Welsh Water or Wessex Water) depending on the area. In some circumstances, there might be a possibility to connect surface water to the highways carrier drain and then the connection point should be agreed with Gloucestershire Highway Authority.

The developer must have agreements in principle from the relevant authorities in place before concluding a method of surface water discharge. These agreements in principle need to be in place for the planning application submission. The details of the drainage proposal could be subject to a drainage condition.

5.3. Control of flows

To minimise the impact of the development on the environment, surface water discharges from the site should not exceed the current run-off rate from the pre-developed condition. The appropriate method of assessing the pre-developed condition is dependent on whether the site is considered to be greenfield or brownfield.

Where run off rates from the proposed development exceed the pre-development rate, attenuation of runoff through the SuDS system shall be incorporated with hydraulic controls used to restrict discharge. A range of storm durations should be used to demonstrate that the system performs appropriately during the design storms (1 in 30 year for no flooding and 1 in 100 year for no internal flooding).

The volume for attenuation storage can be provided after accounting for interception storage and long term storage.

In comparison of the pre-development and post-development conditions, consideration of urban creep (such as the installation of patios and drives) must be included in the calculations. This is covered in the Code of Practice for Surface Water Management for Development Sites (BS8582).

To prevent frequent blockage of any outfall device, caused by the need for small hydraulic controls, the minimum practicable discharge rate for any outfall in Gloucestershire is 5l/s. BS8582 provides further information on this.

For the design to demonstrate that it is not reasonably practicable to control to the determined runoff rate using SuDS, the application must show that

- The volume of storage required would lead to the development becoming unviable;
- The volume of storage required could not be accommodated on the development site.

5.3.1. National Standards

Greenfield discharge rates are applicable to development of land that has not previously been built on. The National Standards require that:

The discharge flow rate for a 1 in 1 year rainfall event will be limited to the 1 year greenfield run-off-rate.

The discharge flow rate for a 1 in 100 year rainfall event will be limited to the 100 year greenfield run-off-rate.

To achieve suitable control at both rainfall events, the SuDS system will require more than one hydraulic control and most likely a multi-level system.

The flow rates shall be calculated using one of the methods outlined below. The Defra / Environment Agency report, Rainfall runoff management for developments[9] provides more information.

An initial estimate of the greenfield runoff rate generally applicable in Gloucestershire is the minimum value of 5 l/s at the 1 in 1 year event. The HR Wallingford website provides an online calculator to make a more detailed initial assessment of greenfield runoff rate: http://geoservergisweb2.hrwallingford.co.uk/uksd/greenfieldrunoff_js.htm

Flow controls appropriate to the site should be applied. For example where flow rates across a wider site should not exceed 2 to 3 l/s, it would be inappropriate to propose a 5 l/s cap.

IoH124

The Institute of Hydrology Report 124 Flood Estimation for Small Catchments (IH124) is appropriate where the site area is between 0 – 200 ha. Where the site is less than 50ha the analysis for determining the peak run-off-rate should use 50ha in the formula and scale it down using linear interpolation.

FEH Method

Where the site area exceeds 200 ha the Flood Estimation Handbook (FEH) method is to be used to estimate the existing run-off rate.

For Greenfield runoff rates, where long term storage is not provided, the peak runoff rate should be limited to QBar (mean annual flood). This is in line with the document, 'Rainfall Runoff Management For Developments' (Section 3.4, page 10).

5.3.2. Brownfield run-off rate

For previously developed and drained brownfield sites, the SuDS systems should modify the runoff rate to achieve minimum of 40% reduction in peak discharges/volumes, but endeavor to reduce flows as close as reasonably practical to the greenfield rates for the same events.

The discharge flow rate, from a brownfield site, for a 1 in 1 year rainfall event should be as close as reasonably practicable to the 1 year greenfield run-off-rate, but at least 40% reduction of existing rates.

The discharge flow rate, from a brownfield site, for a 1 in 100 year rainfall event should be as close as reasonably practicable to the 100 year greenfield run-off-rate, but at least 40% reduction of existing flows.

[8] Available from Defra website http://evidence.environment-agency.gov.uk/FCERM/Libraries/FCERM_Project_Documents/Rainfall_Runoff_Management_for_Developments_- Revision_E.sflb.ashx [Accessed 15 February 2015].
[9] Available from CEH website http://www.ceh.ac.uk/products/publications/documents/ih124floodestimationsmallcatchments.pdf

Rational method

In the absence of computational hydrology models, the Rational Method is acceptable to calculate existing flows for simple sites and can be used on brownfield areas:

$Q_p = 2.78\ C_v C_r\ i\ A$

where:

Qp = peak run-off in litres per second (l/s)

A = impervious area being drained in hectares (ha)

i = rainfall intensity in millimetres per hour (mm/hr)

C_v = volumetric runoff coefficient, which is dependent on the catchment characteristics

C_r = routing coefficient. A value of 1.3 is appropriate

Alternatively, the capacity of the existing outfall pipe should be used to benchmark existing flows from the brownfield site.

It is possible that previously developed land, which has not been used for more than 10 years, may no longer be able to discharge into the local sewer (as a result of interim developments). An agreement with the relevant sewerage undertaker must be in place to secure planning approval for the development.

5.4. Volume control

Attenuation storage is required to satisfy the requirements of the peak flow control.

5.4.1. Interception storage

Interception storage is the collection and treatment of the first part of the surface water runoff (called 'first flush'). This is especially important during rainfall after a period of dry weather, where the first part of the storm washes the surface of oils and other pollutants. It is important that such contaminants are not allowed to enter the receiving watercourse.

Interception storage should be provided to prevent runoff from the first 5mm of rainfall.

Interception storage could be provided through use of source control or similar to enable the interception losses. This first flush should be intercepted either through source control or within the treatment train. Suitable solution types to achieve this include filter strips and permeable paving to cleanse the first flush before it enters the rest of the system.

5.4.2. Long term storage

Long term storage is the volume of water to be stored and allowed to infiltrate, or slowly discharged. It is intended to mimic the slow movement of water through the soils over the days after a storm event. It must be contained in a separate area from the attenuation storage.

Where the site is previously developed, then the volume should be constrained as close as possible to the greenfield value and certainly not exceed the previous brownfield value. All applications must demonstrate that runoff volume control is achieved in line with these requirements.

5.4.3. Climate change

The assessment must make due allowance to the effects of climate change over the lifetime of the development. Official advice is contained on page 11 of the Technical Guidance to the National Planning Policy Framework.

Climate change should be taken into account by applying change factors in line with the guidance. These change factors quantify the potential change (as mm or % depending on the variable) to the baseline. The development design must plan for the change factor covering the whole of the development lifetime.

Changes to river flow

These are provided in the NPPF and are tabulated in Table 5-1 below. The data indicates up to a 20% increase in flows after 2025. The percentages are changes to a 1961 to 1990 baseline.

Changes to rainfall

Climate change will also affect rainfall. It is recommended that changes to rainfall presented in Table 5-1 below are used.

Table 5-1 - Recommended national precautionary sensitivity ranges for peak rainfall intensities and peak river flows

Parameter	1990 to 2025	2025 to 2055	2055 to 2085	2085 to 2115
Peak rainfall intensity	+5%	+20%	+20%	+30%
Peak river flow	+10%	+20%		

[10] Environment Agency (August 2011), Adapting to Climate Change – advice for flood and coastal erosion management authorities

[11] http://ukclimateprojections-ui.defra.gov.uk/ui/start/start.php

5.4.4. Exceedance

Precautions must be taken to ensure that any failure of the SuDS system occurs in a safe manner

Developers must demonstrate they have considered the possibility that their drainage design might fail even if the system is designed for 100 year storms with allowance for climate change.

A backup plan for this eventuality should be developed, which means designing for exceedance. For example overland flow should be routed away from vulnerable areas.

This approach should consider the impact of, for example, blockage on outlets, overland flow routes, over-design events and worsening external constraints (such as tidal impacts, failure of any local flood defences etc.).

A clear hierarchy of flow routes including low flow routes, overflows and exceedance pathways must be demonstrated in SuDS design to show how every day flows pass through the site with predictable routes if blockage or design exceedance occurs.

- Low flow routes – day to day flows are conveyed by a variety of low flow channels through open space between SuDS features and onward to the outfall from the development;
- Overflows – overflow routes between SuDS structures are important in the event of blockage or local surcharge so that runoff can flow to the next part of the management train or the exceedance route without risk to people or property;
- Exceedance – when rainfall overwhelms the SuDS system then overland exceedance routes show where water will flow from development with minimum risk to people or property.

5.5. Natural runoff patterns

SuDS are required to match natural drainage routes, infiltration rates and discharges as far as possible.

The drainage design should look to reduce the overall volume and rate of surface water runoff from the site, over and above the control of any increase in runoff resulting from redevelopment. Such betterment has wider impacts on the community, such as improving the land drainage situation downstream of the site.

Furthermore, the design must take into account all water on the site up to the discharge point, including water that may enter the land via neighbouring land, higher land, or piped or open watercourses.

Use of SuDS which are reliant on pumping, consume energy or which require specialised maintenance are discouraged.

All drainage designs should work with natural topography and gravity, and minimise use of synthetic materials. Bioengineering approaches will give a softer and more natural feel to features and promote infiltration and wildlife.

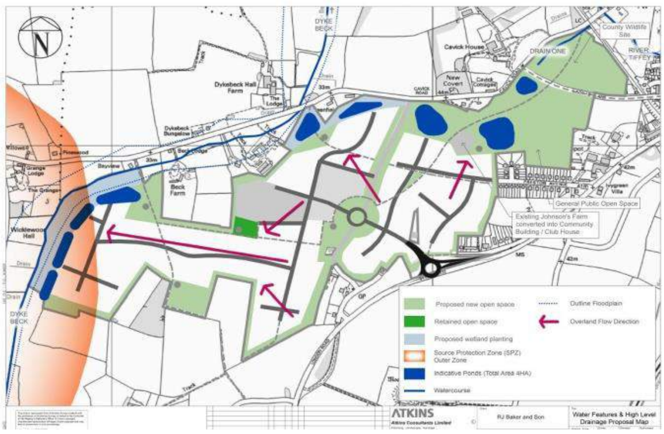


Figure 5-1 – Site planning to consider flow routes following natural flow patterns

One of the main concepts of SuDS is that they mimic natural processes, and we therefore favour systems that avoid the use of pipes or storage tanks. Below-ground features are not sustainable in the long term as they are not easily maintainable and have a limited life in comparison to grassed and more natural systems.
SuDS must not be located in the 1 in 100 year floodplain or in areas identified in any site specific flood risk assessment.

5.6. Planning for sustainable drainage

SuDS should be considered as early in the planning process as is feasible

As SuDS can impact far more visibly and dramatically on a development than conventional drainage, an integrated and multi-disciplinary approach to site planning and design is the key to a successful SuDS system. Drainage engineers, highway engineers, landscape architects and ecologists should all be involved.
Investing in the design and identifying the requirements, issues and opportunities for SuDS at the early stages of a project will be repaid in the long-term. The advantages include:

- saving time later in the design and application process by focusing attentions and efforts;
- SuDS requirements will inform the layout of buildings, roads and open spaces, which can reduce land-take and minimise iterative design;
- where soil types vary across the site, SuDS features could be located on permeable soils to reduce the amount of storage required;
- existing landscape features can be integrated in the design to reduce costs and features can be designed and located to enhance the desirability of a scheme.

The following series of diagrams have been adopted from Planning for SuDS (CIRIA, 2010). They illustrate how SuDS design can be integrated within the planning process and influence the layout of developments.

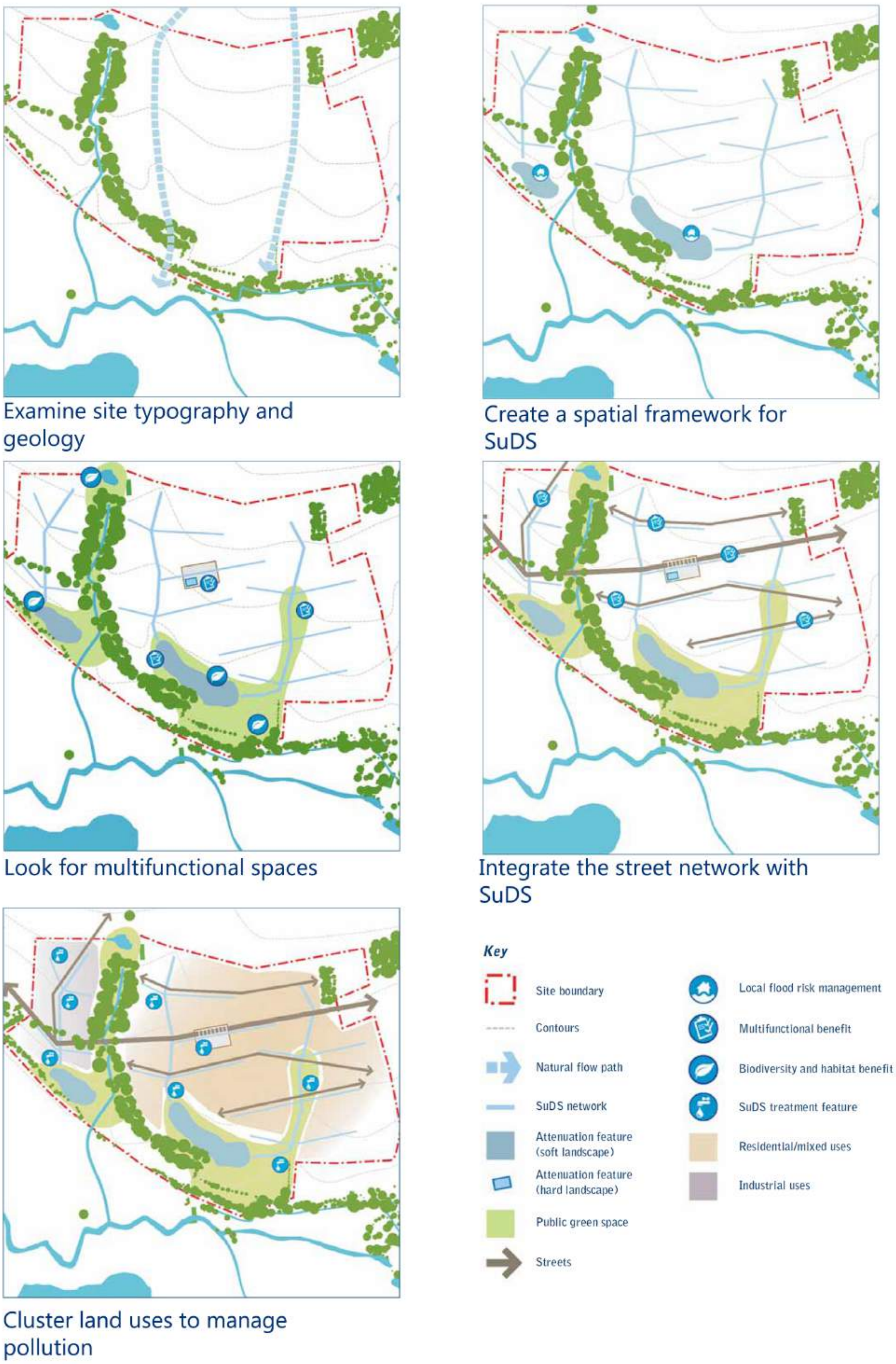


Figure 5-2 – SuDS Design in the Planning Process (Source: CIRIA)

5.7. Source Control/Site Control/ Regional Control

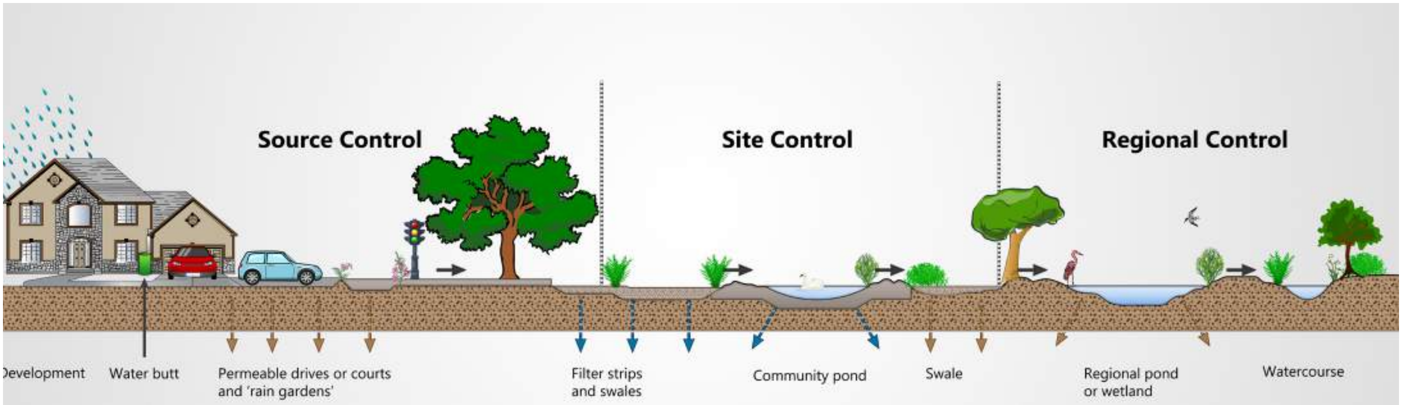


Figure 5-3 – SuDS Management Train (Source: CIRIA)

There are a number of ways in which surface runoff could be routed through the site. SuDS use a number of techniques to manage runoff as it flows through the management train sequence within development.

Source Control SuDS are usually associated with the street landscape or similar areas within development and include filter strips, swales, filter drains, permeable pavement and small detention basins. Source control techniques should be incorporated at the beginning of the management train to intercept silt and pollution and reduce the flow of runoff.

These source control features can be managed by a number of bodies depending on who takes responsibility for the SuDS and on the adoption process. The County Highways Department may take responsibility for roads and pavements, whilst Management Companies may be needed in other cases.

Features such as green roofs, rain gardens, soakaways and permeable paving treat and store water where it falls. They reduce the storage volumes, flow rates and need for additional treatment stages.

As well as considering health and safety and flooding issues, designers should bear in mind how vegetated SuDS features in close proximity to development will be perceived. In order to slow and treat run off effectively, the traditional neatly manicured landscape may need to give way to a more informal aesthetic.

Figure 5-4 – Source control measure as part of a development (Springhill, Stroud)

Once runoff has passed through initial source control features it usually flows to a site control such as a detention basin, pond or wetland often located in green space within or just outside the development boundary. Regional controls, which deal with larger volumes of clean water from more than one development, may be present in public open space. These SuDS features comprise Public Open Space SuDS and may be considered for adoption by the Local Authority.

The opportunity for regional control may be identified if there are existing features on or nearby to the development site that could provide a wider management of runoff. This could encompass more than one site.

For example, it may be that an area has been identified for flood (surface water) storage in a Surface Water Management Plan (SWMP).

Currently Gloucestershire County Council have produced SWMPs for the following areas:

- Cheltenham
- Tewkesbury
- Bishops Cleeve, Southam and Woodmancote
- Gloucester, Churchdown and Innsworth

Some areas put forward for development would need to have some regional SuDS control. It is recommended to contact us to discuss these requirements at an early stage.

06 Landscape design and SuDS

06 Landscape design and SuDS

6.1. Key Principle

SuDS should be sensitively designed to enable it to integrate with the rural and urban landscapes of the county.

6.2. Background

Within the county there are several distinct landscape character types, each determined by the presence of landscape features such as rivers, water bodies, land cover, land form and traditional building styles.

The key features of the local landscape character types should be used to inform the choice and design of SuDS features used in each development, ensuring they are sensitively considered and appropriate to the given location.

Landscape architects and designers, working in collaboration with water management engineers, as part of a fully integrated design team can bring the necessary skills to visualise, plan and design developments which integrate sustainable surface water drainage systems, whilst making best use of available land for a wide range of functions.

With creative thinking and good planning, SuDS can play a significant part in creating better places for the county's communities to live and work.

The multifunctional uses of sustainable surface water drainage systems are an increasingly integral part of our green infrastructure. They help maintain and build ecological function in urban areas, particularly as part of a network of green and blue corridors through the use of swales, ponds and wetlands to perform natural drainage processes by absorbing or attenuating water to reduce flood risk across developments.

A well designed SuDS can perform its primary function of reducing flood risk, but can also add value through the enhancement of habitat and biodiversity, the provision of informal recreation and education and visual amenity. Furthermore by using the landscape to manage rainfall and harness water in a creative way, SuDS can help safeguard the landscape character of river systems and reinforce local distinctiveness.

6.3. Good Practice

The following sets out a number of landscape considerations when developing a SuDS design:

- Blending the skills of the drainage and flood risk engineer, with a landscape architect in the design of SuDS solutions that are fully integrated with the development can create good quality places which people wish to live and work.
- Every effort should be made to create multi-functional drainage assets, including new habitats that enhance nature conservation, informal recreation space and amenity value alongside opportunities for education and learning.
- Consideration of the Gloucestershire Landscape Character Assessment[1] is carried out at the earliest stage to ensure that the SuDS design takes account of the existing character and serves to meet the objectives of the council to conserve, protect and enhance the landscape.
- Consideration should be given to the surrounding landscape or townscape character when undertaking planting design and plant selection, for example the use of extensive reed bed systems would not be appropriate in high density development areas, but would be suitable in areas of the county characterised by the presence of water meadows.
- Careful consideration is given to the siting, layout and landform of the SuDS design to ensure it is fully integrated with the site and in the landscape, and takes full account of the site constraints. Particularly with regards to access requirements and health and safety issues for site users and maintenance operatives.
- Plant choice should be carefully considered to ensure the species selections are suited to the function of the SuDS design, including the range in water levels and anticipated moisture conditions of the SuDS asset, and avoid the application of herbicides and fertilizers, or other chemical applications, which can cause pollution within water courses.

[1] http://www.gloucestershire.gov.uk/media/adobe_acrobat/7/c/2017_Gloucestershire_LCA_c.pdf

- In high density developments there may be limited opportunity to incorporate extensive areas of soft landscaping. However it is still possible to use hard engineered SuDS solutions in these locations, such as permeable pavements, channels or rills. Such assets can be designed to create a feature to add amenity value to the development through the selection of hard landscape materials and consideration of the layout and design of the system.
- SuDS in new developments within urban areas should consider the use of hard landscape treatments to reflect the setting and context of the area to enhance local distinctiveness, whilst avoiding incongruous details and material finishes.
- The planting of native trees and woodlands help mitigate the effects of climate change through interception to rainwater infiltration into the ground, thus reducing the risk of flash flooding on a development site. Tree planting can further reduce urban heat island effect by reducing air temperatures through shading and improving air quality;
- Consider the whole watercourse catchment in each development, for example tree planting in upstream catchment areas can assist in mitigating downstream and site specific flooding. This could equally be a consideration where development sites have limited space for green space, and tree planting could be provided within appropriate off site locations.
- The inclusion of green roofs on buildings with flat or gently sloping roofs can be used to intercept rainfall, reduce surface water run-off, add habitat and biodiversity value, and visual enhancement.
- SuDS designs should be resilient to the dynamic nature of our environment, the solution should consider and plan for future adaptation as a response to climate change.

Figure 6-1 – Green roof on a school

07 SuDS and water quality

07 SuDS and water quality

7.1. Key principle

Gloucestershire County Council intend that all SuDS installations will provide no deterioration of water quality to surface waters or groundwater from new developments.

7.2. Introduction

Gloucestershire has surface waters and groundwater areas of varying quality as shown by the River Basin Management Plan quality assessments on the Environment Agency website.

These include surface water bodies (and their catchments) such as the Severn, Thames, Windrush, Frome and Cam.

Gloucestershire also has a number of source protection zones[2] where water is abstracted for drinking water and groundwater aquifers that retain water for human and environmental purposes.

Further information on the quality of rivers and location of designated conservation sites can be found on the Environment Agency and MAGIC websites (See Section 8.6).

New development can cause pollution of water through sediments, PAH's (hydrocarbons) and soluble pollutants. For some developments, particularly highways there may also be a risk of spillage. The level of pollution will depend on the type of development.

The level of treatment required will depend on the level and type of pollutant, and the sensitivity of the receiving water course and ground water. One of the Water Framework Directive requirements is that there is no deterioration in any element of water body classification which includes chemical and ecological water quality. To ensure this sustainable drainage systems should be used wherever possible.

7.3. Treatment stages

The recommended number of treatment stage components is outlined in the CIRIA SuDS Manual C697 and presented below in Table 7.1

Table 7-1- Recommended SuDS treatment stages

	Receiving watercourse sensitivity		
Run off characteristic	Low	Medium	High
Roofs	1	1	1
Residential roads and parking areas	2	2	3
Refuse areas, industrial, areas, loading bays and parks, general highways	3	3	4

It is important to highlight that this sets out the minimum number of components required at each site and that each site should be reviewed on a risk assessment basis. An increased number of components will generally be required for larger sites to meet all design criteria. Larger sites should not drain to a single location, but should be split into sub-catchments and several smaller features, including those that drain to a final site control.

7.4. The importance of capturing small regular events

Small, frequently-occurring storms tend to produce the majority of run-off events (and pollution) from new developments.

Gloucestershire County Council requires that all sites provide treatment for the first 5mm to 10mm of run-off which typically will capture the majority of the pollutant load in surface water run-off onsite.

To enable this at least one treatment stage should be considered and this will provide what is known as source control. Filtration strips and permeable pavements might be a suitable example of this.

7.5. Physical processes of removing pollutants and SuDS selection.

A treatment stage should be related to the physical process involved in removing a pollutant.

[2] http://maps.environment-agency.gov.uk/wiyby/wiybyController?x=383500.0&y=218500.0&topic=groundwater&ep=map&scale=9&location=Gloucester, Gloucestershire&lang=_e&layerGroups=default&distance=&textonly=off#x=383500&y=218500&lg=1,10,&scale=4

Figure 7-1 – Examples of source control including, swales, permeable paving, bioretention and green roofs (clockwise from top left)

The processes by which pollutants such as sediments, PAH's and soluble metals can be removed vary from pollutant to pollutant but can include settlement, filtration, uptake by plants, biodegradation, absorption, precipitation and photolysis. The various SuDS techniques also offer different levels of pollution treatment and tackle different contaminants. Table 7.2 gives an indication of these.

Table 7-2 - Water quality performance selection matrix (Table 5.72 of the CIRIA SuDS manual)

SuDS Group	Technique	Water quality treatment potential				
		Total suspended solids removal	Heavy metals removal	Nutrient (phosphorous, nitrogen) removal	Bacteria removal	Capacity to treat fine suspended sediments and dissolved pollutants
Retention	Retention pond	H	M	M	M	H
	Subsurface storage	L	L	L	L	L
Wetland	Shallow wetland	H	M	H	M	H
	Extended detention wetland	H	M	H	M	H
	Pond/wetland	H	M	H	M	H
	Pocket wetland	H	M	H	M	H
	Submerged gravel wetland	H	M	H	M	H
	Wetland channel	H	M	H	M	H
Infiltration	Infiltration trench	H	H	H	M	H
	Infiltration basin	H	H	H	M	H
	Soakaway	H	H	H	M	H
Filtration	Surface sand filter	H	H	H	M	H
	Sub-surface sand filter	H	H	H	M	H
	Perimeter sand filter	H	H	H	M	H
	Bio-retention/filter strips	H	H	H	M	H
	Filter trench	H	H	H	M	H
Detention	Detention basin	M	M	L	L	L
Open channels	Conveyance swale	H	M	M	M	H
	Enhanced dry swale	H	H	H	M	H
	Enhanced wet swale	H	H	M	H	H
Source control	Green roof	n/a	n/a	n/a	n/a	H
	Rain water harvesting	M	L	L	L	n/a
	Permeable pavement	H	H	H	H	H

H=High Potential; M=Medium Potential; L=Low Potential

More information on removal processes can be found in the CIRIA SuDS manual.

Gloucestershire County Council prefer the use of above ground, "green" sustainable drainage systems to provide the removal mechanism.

However, in certain situations below ground or proprietary sustainable drainage solutions may be more appropriate.

7.6. Further information sources

Links to the data sources referred to in the section are contained in Table 7.3 below.

Where it is considered necessary to estimate treatment efficiency for removal of pollutants guidance CIRIA C609 and the Design Manual for Roads and Bridges (currently HA103/06 and HD45/09) should be consulted along with current best practice guidance.

Table 7-3 – Further information sources

Source	Data available	Weblink
Environment Agency	Surface river and groundwater WFD importance and location of source protection zones	http://maps.environment-agency.gov.uk/wiyby/
MAGIC	Location of statutory and non-statutory guidance.	http://www.magic.gov.uk
CIRIA C697 and CIRIA C609	Information on removal mechanisms and general design guidance	www.ciria.org
British Water SuDS guide	Information on made sustainable drainage solutions.	http://www.britishwater.co.uk/how_we_do_it/SUDSFG.aspx
DMRB	Some data on efficiency of removal	http://www.dft.gov.uk/ha/standards/dmrb/
UK SuDS Tools Website	Tools for site drainage design and evaluation	http://geoservergisweb2.hrwallingford.co.uk/uksd/
Susdrain	A range of resources for those involved in delivering sustainable drainage, water sensitive urban design etc	http://www.susdrain.org/

08 SuDS, Biodiversity and Amenity

08 SuDS, Biodiversity and Amenity

8.1. Key principle

Gloucestershire County and District Councils intend that all SuDS installations will protect the existing environment and where possible enhance it. This covers both biodiversity in terms of habitats and species, but also amenity value to the owners and occupiers of development sites.

Gloucestershire is a wonderful county for wildlife - important habitats, rare and protected species and a wide diversity of animals and plants. This biodiversity is a consequence of the county's varied land form, geology, soils, habitats and built structures, which in turn have been influenced by farmers, estate owners, conservationists, developers and others.

The importance of Gloucestershire's biodiversity is recognised in that numerous areas of the county are covered by international, national and local nature conservation designations.

8.2. Guidance/ Legal requirements

SuDS should be used to maximise the ecological diversity in line with national and local policies. This is underpinned by various legislation including a biodiversity 'duty' for public bodies which is captured within the Natural Environment and Rural Communities (NERC) Act 2006.

SuDS provide opportunities to create a variety of habitats for wildlife due to the need to manipulate topography and encompass water. These features provide opportunities for people to experience wildlife within the site. For example, the pleasure in watching and listening to song birds is an experience for residents in built-up areas, adding quality to people's lives. There is an increasing body of evidence which demonstrates the socio-economic value of wildlife collectively referred to as 'ecosystem services'.

The wildlife value of existing habitats and surrounding terrestrial areas should be surveyed by a suitably qualified and experienced ecologist during the early planning stages. Particular attention should be given to any protected species and sites as well as any habitats and species of principal importance (defined under the Natural Environment and Rural Communities (NERC) Act (2006).

The drainage design should:

- ensure protection for existing habitats from flooding events
- locate SuDS features close to, but not directly connected to, existing wet areas, so plants and animals can naturally colonise the new SuDS ponds
- create features with a range of moisture gradients
- ensure only native plants of local provenance are used.

To assist Gloucestershire County Council and other partners with the delivery of its NERC Act duty, Gloucestershire County Council has created Gloucestershire's Local Nature Partnership, which builds on the content of the old biodiversity action plan. The partnership is a strategic organisation promoting the conservation and enhancement of Gloucestershire's wealth of habitats and species. More information is available from their website http://gloucestershirebiodiversity.net/.

Developers are encouraged to reflect on the information contained on the website whilst designing their SuDS in order to maximise the contribution they can make to wildlife.

SuDS should be designed with guidance from ecologists to ensure that the proposed vegetation and habitats are appropriate. Furthermore, the attenuation and flow depths should be considered in the species selection process. The Gloucestershire Nature Map has an associated Plan which includes information on Priority Habitats. There are 8 priority habitat groups identified in Gloucestershire:

- Lowland farmland;
- Wetlands;
- Woodlands;
- Coastal;
- Lakes and Ponds;
- Rivers;
- Urban and Brownfield; and
- Uplands

As a more integrated landscape-scale approach to biodiversity conservation is now being pursued in Gloucestershire, these provide a wider approach to recovering habitats and the ecosystems and services they support. Also available from the Gloucestershire biodiversity website are the original Habitat Action Plans (HAPs), produced for the original Biodiversity Action Plan released in 2000.

Several of the priority habitat groups can be supported by well-designed SuDS for example Wetlands, Lakes and Ponds, and Urban and Brownfield. In general, biodiversity gain can be achieved through innovative, good design and creation of spaces for sensitive flora and fauna. This guidance strongly encourages developers to integrate biodiversity within SuDS as frequently as possible.

The provision of such habitat rich areas will, to some extent, be dependent on the location of the SuDS (for example an urban street setting would be less likely to support such good biodiversity, but can still contribute green space and habitat and can add quality to people's lives).

There are requirements for Water Framework Directive compliance assessments for all new developments if they affect waterbodies. Under this European legislation, no deterioration to the waterbody is permitted.

8.3. Amenity Good Practice

- SuDS should be integrated into open space to provide amenity benefit to the site and its occupiers. For example, house buyers might benefit from the areas for dog-walking. SuDS that are designed with aesthetics in mind will ensure public acceptability and can be beneficial to the public realm.
- Key considerations to provide amenity benefit are the use of vegetation and landscaping techniques, linking open water areas to recreation sites, setting an appropriate maintenance programme to ensure areas are visually attractive throughout the year and informing and educating the users of the role of SuDS.
- Sustainable drainage can be integrated with open space provision and used for recreation. It is essential to consider SuDS as part of a broader green infrastructure rather than stand-alone, bolt-on features. SuDS should be an integral part of the landscape, providing amenity space, storing and treating run off, alleviating flooding, and enhancing biodiversity.
- Features such as ponds, detention basins and swales bring controlled water, undulating landforms and nature to people's doorsteps which is the sought after addition to many developments.
- SuDS can be designed to accommodate large volumes of water during heavier rainfall events but remain dry the rest of the time to allow for recreation and events. Boardwalks, stepping stones and bridges can be provided to allow access across wetter areas. Ground slopes require particular consideration with regard to health and safety and designs should concentre on shallow gradients. All SuDS systems should also avoid small stagnant pools which could lead to waterborne nuisances such as midges.
- Ensuring that SuDS remain safe and accessible for the life-time of the developments they serve is principal to design. Along with other aspects, health and safety must be considered at the pre-application stage. Shallow water depths, strategically placed vegetation and stable ground around water margins can help to create a safe environment for site users.
- The desire should be to create areas of quality open space which encompass the storage of surface water, amenity and enhancement of biodiversity.

8.4. Biodiversity Good Practice

In order to improve the biodiversity value of SuDS systems in Gloucestershire, a number of general recommendations are set out below. These apply mainly, but not exclusively to ponds and wetland features:

- The wildlife value of existing wetland habitats and surrounding terrestrial areas should be surveyed by suitably qualified ecologists during early planning. Protected species and sites should also be identified around any proposed locations. Hydrological surveys will inform existing surface and ground water flow and are recommended to ensure proposed changes do not affect water quantity or quality.
- Where possible, new SuDS features should be located in close proximity to, but not directly connected with existing wetland areas, this will minimise risk that existing habitats will deteriorate.
- Crossovers (bridges, culverts, etc.) should be kept to a minimum and balanced with people access/connectivity between neighbourhoods and places.
- It is suggested that only one third of a linear water feature should be accessible by the public to minimise disturbance.
- Maintenance tracks/ paths should not be accessible by

the public, in order not to disturb feeding and nesting faunal species and some protected species. It is recognised that this may not be practical.

- Consider whether planting will rely on natural colonisation or be established with planting regime.
- Use locally appropriate native species where possible when using a planting regime, if possible use plants of regional origin (see suggestions for planting list in Section 9.6.3.3) Wetlands. Where appropriate, the species mix should aim to create habitats that contribute to the Gloucestershire Nature Map, along with regional and national Biodiversity Action Plans.
- Where possible use locally appropriate native species.
- Any planting regime, should be appropriate for the location and available habitat, relative to top soil present, gradient, water depth and soil moisture and with respect to access and maintenance. For example, a swale may have a very dry soil/moisture profile at the top of the bank, while the bottom of the bank is more likely to be wet. Careful plant choice will ensure planting survives and is self-sustaining.
- Consider planting design and ensure this does not adversely impact highway visibility and safety requirements.
- Where possible, create biodiverse/species rich habitats, within ponds/ wetlands through the creation of different water depths, deep water, marginal habitat and dry/damp areas. Avoid hard engineered and smoothly finished surfaces they provide less physical habitat diversity for plants and animals.
- Provide sufficient treatment upstream of any pond/wetland feature to allow design amenity and biodiversity objectives to be delivered.
- Planting design needs to balance need to rapidly establish stabilised vegetation against potential for biodiversity gain. It may, for example, be appropriate to quickly establish a low diversity grass and manage this to increase species diversity over time. Careful consideration needs to be given to top-soil specification, floral diversity can be promoted by thinner more species poor soils, but these will establish more slowly.
- Planting designs should avoid need for use of fertilizers. Maintenance should seek to require physical cutting only, with no application of herbicide, fertilizer or other chemical applications, which might pollute water courses.
- During construction, care should be taken in and around SuDS features to avoid compaction of subsoil and topsoil. In particular through excessive tracking of machinery. When compaction occurs roots are unable to penetrate the soil.

It is good practice to include wildlife piles, or hibernacula, in your designs. They are a useful and sustainable method of green waste disposal which can be employed where the pollutant risk is low (as defined in the water quality section in Section 7). Ideally created in areas adjacent but set back from the SuDS they create a cost effective and natural wildlife resource which can also offer education opportunities in their creation and maintenance/monitoring.

Hibernacula can provide additional safe haven for amphibians and reptiles, they can also be designed to create additional accommodation for solitary bees or wasps. These features fit well with SuDS design and when located near water they will be particularly suitable for amphibians. These features can be created at the same time as the SuDS feature using the spoil from the pond/ wetland.

You should orientate the hibernacula on an east-west axis, so that one side is south facing.

To construct, pile logs/ rocks and inert material which may have been excavated from the SuDS feature and cover with logs or brash taking care not to block any of the gaps that create access points for amphibians into the mound. Cover the brash with grass cuttings, prunings and soft waste to around 1.5m.

Hibernacula should be free draining. The pile will heat up during the summer and attract animals that need heat to incubate their eggs and young. The pile can be maintained as material is available, with additional piles created as necessary. After 5 years the pile can be carefully dismantled and used as compost and the process repeated.

8.5. Criteria for evaluation

The following lists a number of criteria for SuDS amenity and biodiversity for evaluating landscape character and wildlife potential.

Amenity

- **Legibility** - telling the water story along the SuDS 'management train' – visibility and understanding.
- **Elemental water** - a controlled flow of clean water before public access or use. Source control must be provided within development.
- **Conveyance and containment** - each component of the SuDS sequence must contribute to landscape quality.
- **Usefulness and SuDS** - each SuDS component must be considered for other uses or as multi-functional space.
- **Inlets, outlets and control devices** - all visible SuDS structures must be attractive, interesting or visually neutral but not ugly.
- **Health and safety** - assess and manage risk for open water, gratings and sumps, slip and trip hazards, flow control structures, and other risks in the landscape.
- **Management** - public acceptance and enjoyment of SuDS requires a clear maintenance strategy to demonstrate the SuDS are cared for and will function for the life of the development

Biodiversity

- **Clean water** - A management train with source control ensures a controlled flow of clean water for biodiversity within development before water enters wetland SuDS features
- **Connectivity** - links between existing and proposed wetland and ponds enhance natural colonisation and habitat resilience for wildlife
- **Structural diversity** - varied profiles both vertically and horizontally provide maximum habitat potential
- **Terrestrial habitat** - opportunities for wildlife enhancement extend beyond wetlands and ponds to provide connectivity and integrated ecological design
- **Nutrient control** - low fertility measures generally promote habitat diversity and reduce maintenance costs (except where needed for a SuDS function)
- **Native planting** - local or national provenance seed and planting ensure habitat integrity with guarantees that recognised alien weeds are absent.
- **Management** - mosaic habitat management with mown access paths and edges ensure wildlife friendly SuDS and public acceptance.

8.6. Consultation

On large or controversial applications it is recommended that you consult with the Environment Agency, Natural England and local wildlife trusts over your plans. This is particularly important where your site is on, adjacent to or close by any designated sites. These consultees will have their own guidance, procedures and rules you will need to follow.

The aim of environmental consultation will be to:

- ascertain the environmental objectives for the site, as influenced by its ecological and environmental features; and
- ascertain the environmental and technical constraints on SuDS design for the site.

Further guidance and information on the environmental and ecological opportunities in Gloucestershire can be found in Chapter 3.6.

09 Components of SuDS

09 Components of SuDS

9.1. Introduction

There are a wide range of SuDS that can be included in the design of a scheme, either separately or as part of a treatment train. The following section provides important information on:

- What the different types of SuDS are;
- How different types of SuDS work;
- How to produce good quality designs;
- How to construct SuDS;
- How to maintain the SuDS once they are built;
- Dos and don'ts for good design;
- Where each type of SuDS is suitable.

9.2. Swales

9.2.1. What is a swale?

A swale is a linear shallow channel which can convey runoff from one place to another, holding water and can, ground conditions permitting, infiltrate water to the ground. Swales can be used in conjunction with other SuDS features to link components. For example, a swale could link areas of permeable pavement and raingardens to retention or detention ponds.

Swales are designed to be shallow depressions with wide shallow slopes to easily integrate into the surrounding landscape, adding amenity to the area. They receive water from sheeting overland flow along their length, from either grass filter strips, piped drainage, or kerbs.

Figure 9.1 – Roadside swale

9.2.2. Where to use

Swales can be used anywhere in Gloucestershire. See Section 3.1 for more information on the underlying geology of different parts of Gloucestershire. In most areas, soils allow for good infiltration rates and therefore swales can be used as pathways to connect rainfall to groundwater. In clay areas where infiltration rates are lower, they can and should still be used to attenuate runoff. Gloucestershire are keen to see more surface SuDS, and would therefore expect strong justification if swales are not to be included in a scheme.

9.2.3. How do they work?

Swales slow the rate of runoff by allowing sheeting flows over a vegetated (normally grass or light planting) surface along a shallow gradient. This mimics the process of natural drainage in fields and upland catchments.

Pollution control is achieved in a swale by forcing a reduced speed of flow, allowing fine sediments to settle in the base of the swale, allowing the vegetation to absorb and filter the runoff. Their linear lengths promote natural treatment of the runoff through a combination of settlement, phytolysis, oxygenation and plant uptake. Swales can directly discharge to watercourses, but are often used as part of a treatment train in conjunction with retention ponds or wetlands, which further slow the conveyance process and provide pollution control benefits.

The storage aspect of a swale can be increased by the inclusion of small check dam structures, from for example, recycled kerbs, or earth mounds, which allow water to pass forward once a certain depth is reached. Rocks could also be used, which can reduce forward flow by providing slow seepage through the gaps in the feature.

The use of such check dams can increase the moisture gradients provided by the swale, allowing increased biodiversity with wet and dry reaches. It may be that the areas upstream of a check dam are lined with clay to further increase the retention of water.

9.2.4. Design

Designed and constructed well, swales can provide efficient and cost effective alternative to traditional piped systems.

Limit velocities during extreme events to 1 - 2 m/s to prevent erosion

Maintain flow depth during frequent events to below the height of the grass or vegetation

Maximum side slopes of 1 in 3

Minimum base width 0.5m

Figure 9-2 - Key design criteria for swales

9.2.4.1. Design considerations

Dry swales are often included into housing developments where large areas of impermeable surfaces are present. Dry swales provide landscaped green area which can be aesthetically pleasing, as well as a practical solution to drainage.

The shallow depression of the swale means they fit well into landscaped areas. They are open and accessible when it is not raining. See example photographs from Upton of a "large" dry swale, and Cambourne of a "wet swale" below.

It should be noted that a swale is not a ditch, but a shallow engineered feature in the topography.

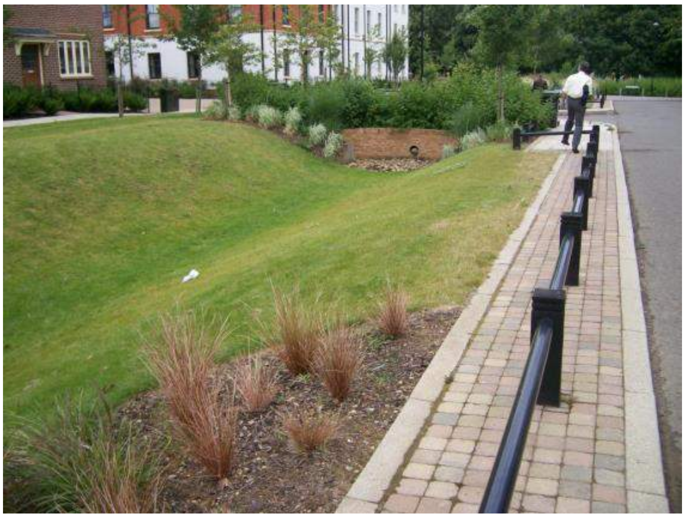


Figure 9-3 - Swale

Figure 9-4 - Swale with lightly vegetated base

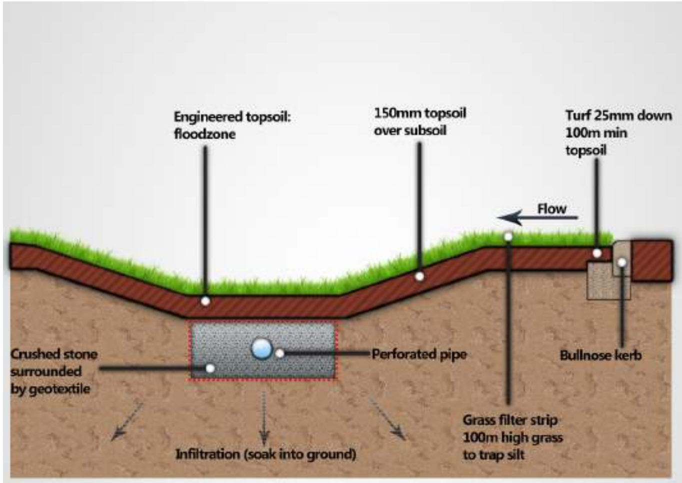


Figure 9-5 – Dry swale (SuDSnet)

A dry swale can include an underlain filter drain to increase the interface with the underlying soils and promote infiltration of runoff. In these under-drained swales, the intention is for a dry feature with limited planting along its base. Any infiltration from the swale will be dependent on soil conditions.

Figure 9-6 – Dry swale during rainfall showing gully outlet (SuDSnet)

This type of swale allows for year round access and amenity of the swale and green area which benefit locations such as; school grounds, residential housing and playing fields.

Wet swales can be used to attenuate water during rainfall and provide spaces of linear wetland where habitats such as reed beds can flourish. This can provide habitat for invertebrates and birds. The planting species should be carefully selected using local provenance stock where possible. A sample species list is given in the section on wetlands (Section 9.6.3.3), although selection should be made by suitably qualified professionals to ensure they are suitable to the conditions presented for the site.

Swales can be successfully combined with highway design to provide sustainable drainage, although care must be taken to ensure any pollutants from the highway are not combined with runoff from clean areas.

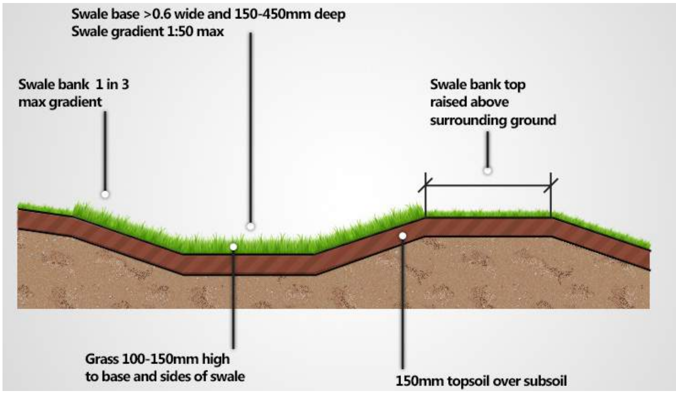


Figure 9-7 – Wet swale

The following design issues should be considered:

- Swales typically use a 1 in 3 bank slope or less, promoting easy access.
- The base of the swale should be between 900mm wide and no more than 2m wide.
- The water in a swale should not reach a depth greater than 450mm, although for normal flows, a depth of 100mm to 150mm should be designed for.
- A freeboard of 150mm could be added to the design although this is not strictly necessary.
- Swales should have a longitudinal gradient of 1:40 or shallower to reduce the risk of erosion during flow.
- The maximum flow velocity should be less than 2m/s, and less that 1m/s where possible.

- For the purpose of design, a Manning's roughness value of 0.250 should be use for treatment flows to 150mm depth, reducing to 0.100 for flow at the design depth of say 600mm (full capacity).
- The swale should be designed at the 1 in 30 year event to provide giving at least one of the flow criteria: an average residence time of 10 minutes to permit sufficient water quality treatment; flow velocity should be less than 0.3m/s; flow depth less than 150mm.
- The storage capacity of a swale can only be considered as part of the design where the outlet from the swale is regulated.
- Swales should not be fenced off so removing any trip hazard.

9.2.4.2. Swales Dos and Don'ts

A summary of the "Dos" and "Don'ts" for swale installation can be seen in the table below:

Table 9-1 – Swale - Dos and Don'ts

Do	Don't
Install last to protect from site use or control erosion using jute, straw or geosynthetic mats and check dams until vegetation becomes established	Compact soil as this will reduce its capacity for infiltration
Limit the flow through the swale to between 1-2 m/s to prevent erosion	Construct within 5m of a tree, unless the root protection is provided
Design as a feature if created as new landform in public open space	Infiltrate where foundations could be effected, unless protection is provided
Install check dams to increase the capacity for surface water storage and to control the flow rate	Design with a longitudinal gradient steeper than 1/40 or side slopes steeper than 1/3
Consider silt traps or sediment control device at each inlet and outlet point of SuDS	Install in high pedestrian area without protective measures

9.2.4.3. Suggested planting list

The following species list provides a generic idea of planting suitable for Gloucestershire SuDS swale features where check dams are included to create localised wet areas. This list is not exhaustive and the exact choice should relate to site-specific conditions.

Where possible, designs which try to create a range of plant communities and habitats across a range of moisture regimes are favourable. Once the location and site conditions have been agreed Gloucestershire County Council advise discussion with specialist suppliers of British wild flowers and grasses who will be able to advise on appropriate natural plant species lists to suit specific site requirement and function.

CIRIA (2007) provides guidance for the planting of swales. The following planting mix is recommended for swale areas, indicative proportions are suggested:

- 10% Iris pseudocorus (Water iris)
- 10% Carex riparia (Great pond sedge)
- 10% Carex Nigra (Common sedge)
- 10% Carex acutiformis (Lesser pond sedge)
- 50% Sparganium erectum (Branched bur-reed)
- 10% Typha angustifolia (Lesser reed mace)

The edges of the swales should be seeded with a normal amenity grass mix with a wildflower component.

9.2.5. Construction

The construction of swales will need to be managed to ensure there is no sediment build up in them during the works.

Whilst the swales are shallow depressions, care should be made on site to ensure no accidental entry in the features are made by plant or machinery.

Figure 9-8 – Swale construction on the London 2012 Olympic Park (before and after)

9.2.6. Maintenance

Maintenance of swales is required to ensure their carrying capacity and ability to pass water from one place to another. Maintenance should be tailored to ensure it looks intentional so people understand this is a maintained feature.

Where the swale is grassed, the sward should be kept at around 100mm high by regular cutting. Grass longer than this is likely to lodge flat and afford a reduced filtration treatment effect. Grass cut much shorter might lead to erosion problems and eventually sediment transport in the drainage system.

Table 9-2 – Swale maintenance requirements.

Maintenance Frequency	Required Action	Maintenance Frequency	Maintenance effort
Regular Maintenance	Litter and debris removal.	Monthly for 1st year, then three times per year	1 site visit with 3 men assuming 1 light van, mower and ancillary equipment.
	Grass cutting – to retain grass height within specified design range of 75-100mm, not to exceed 150mm, leaving cuttings in situ	Monthly for 1st year, then three times per year	Included in above site visit
	Manage other vegetation and remove nuisance plants. Wetland or vegetation cut at 50mm with cuttings removed	Monthly for 1st year, then three times per year	Included in above site visit
	Check for poor vegetation growth due to lack of sunlight or dropping of leaf litter, and cut back adjacent vegetation where possible.	Annually	Included in above site visit
	Re-seed areas of poor vegetation growth. Alter plant types to better suit conditions, if required.	Annually	Included in above site visit
	Inspect inlets, outlets and overflows for blockages, and clear if required.	Monthly for 1st year, then three times per year	Included in above site visit
	Inspect infiltration surfaces for ponding, compaction, and silt accumulation. Record areas where water is ponding.	Monthly for 1st year, then three times per year	Included in above site visit
	Inspect inlets and facility surface for silt accumulation. Establish appropriate silt removal frequencies.	Half yearly	Included in above site visit
Occasional Maintenance	Repair erosion or other damage by re-turfing or reseeding. Sediment removal and rehabilitation of swale base	Every 5 years	For a swale area up to 1,000m², assume 1 site visit with 3 men, 1 light van, small excavator and ancillary equipment.
	Re-level uneven surfaces and reinstate design levels.	Every 5 years	Included in above rehabilitation works
Reactive Actions	Scarify and spike topsoil layer to improve infiltration performance, break up silt deposits and prevent compaction of the soil surface.	As required	Included in above site visit
	Remove and dispose of oils or petrol residues using safe standard practices.	As required	Included in above site visit

9.3. Filter strips

9.3.1. What is a filter strip

Filter strips are gently sloping sections of densely vegetated land, usually covered in grass, that are used as a buffer to intercept uncontrolled overland flows from impermeable surfaces. For example; a filter strip may be placed next to a pavement, roadway or other impermeable surface where surface water is likely to run off onto surrounding land in an uncontrolled manner.

They are often used as pre-treatment upstream of other SuDS techniques to provide an extra level of treatment and to extend the life time of the downstream SuDS.

Figure 9-9 - Grass filter strip at the edge of a parking area (Susdrain)

Filter strips have a low-medium diffuse pollutant removal potential; therefore they should always be linked with other SuDS as part of a SuDS management train. Filter strips treat run-off by vegetative filtering, which reduces particulate pollutant levels by removing sediments, organic materials and trace metals.

9.2.2. How do they work

The purpose of a filter strip is to intercept this uncontrolled runoff and slow the flow before the water reaches the next stage in the SuDS downstream. They are not a single SuDS solution and should be used in conjunction with other SuDS options.

The primary purpose of filter strips is to slow overland flows and to intercept pollutants (such as oil or diesel) and silt. The dense vegetation helps to trap silt that could otherwise lead to blockages in the drainage system downstream. Filter strips can also help to trap and over time break down pollutants, preventing them from ever entering the watercourse.

Filter strips also allow some of the water to naturally soak into the ground, although this volume is relatively small compared with other types of SuDS it does provide the essential interception storage component required by the standards. By allowing some of the overland flow to infiltrate at the beginning of the SuDS train, it reduces the burden of flows on the downstream sections of the system.

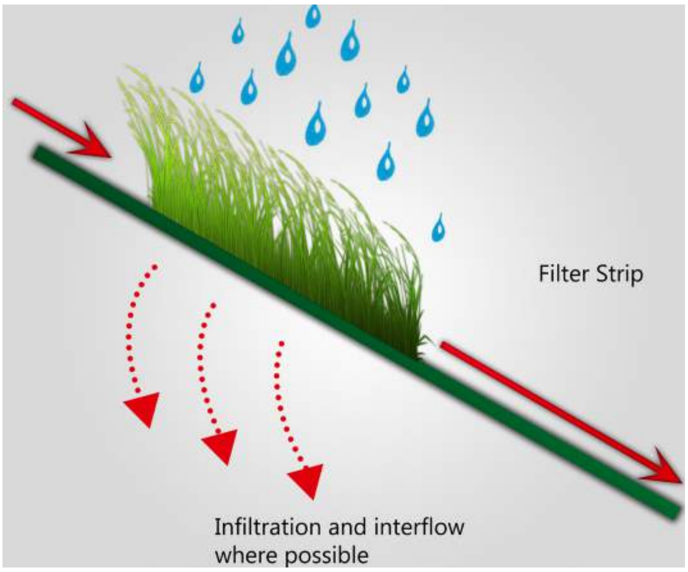


Figure 9-10 – Planted filter strip (Hertfordshire County Council)

9.2.3. Design

have a permanent pool volume for water quality treatment

provide temporary storage volume for flow attenaution

create a sediment forebay to capture suspended solides or use pre-treatment

have a length to width ratio of between 3:1 and 5:1

use a minimum depth in open water of 1.2m

use a maximum depth in the permanent pool of 2m

have side slopes / banks less than 1 in 3

Figure 9-11 - Key design criteria for filter strips

9.2.3.1. Site and planning considerations

The filter strip is intended to provide an opportunity for infiltration of water into the ground, and filtration of sediments from the surface water runoff. As such, the filter strip should be protected from overcompaction and flattening of the grass. Preventing vehicle access onto filter strips is crucial – and so specification on hand mowing or lightweight plant needs to be made. However, access for maintenance is still required.

The filter strip should be readily incorporated into the landscape to reflect nature and site context. Wide grassy verges or amenity areas can be readily accepted.

Filter strips can vary in width but the greatest benefit is obtained from wider strips. The recommended width of filter strips is 6m, but given site constraints, a minimum width should be set at 1m to allow for mowing and maintenance. Over-run by vehicles must be prevented using bollards, rails, fences or other controls to retain an even grass surface for flow. The kerb haunch height must allow a minimum of 100mm topsoil at the edge for acceptable grass growth to prevent erosion with 150mm topsoil generally in all other grass areas. These sizing requirements need to be considered early in the site layout planning.

9.3.4. Design considerations

Some of the main aspects to consider are included below:

- Surface water flows from any paved area must be able to run over a flush kerb onto the vegetated filter strip – this could be along the entire length, or in discrete sections.
- The filter strip should be constructed some 20mm to 25mm lower than the flush kerb to allow unimpeded flows and reduce the risk of ponding – a drop any higher might lead to erosion of the filter strip.
- Levels along the length of the filter strip transition should be consistent which will help to reduce the likelihood of erosion due to concentrated flows.
- The slope of the filter drain should be greater than that of the impermeable surface upstream to ensure required flows.
- The maximum slope across the filter strip should not exceed 1 in 20 slope and should be greater than hard surface to ensure adequate flow.
- A suitable depth of topsoil should be installed to ensure dense vegetation growth across the filter strip; this should generally be between 100-150mm of topsoil, depending on local conditions.
- The filter strip must be designed with slopes of less than 1 in 3 to allow for maintenance and more appropriately less than 1 in 20.
- Whilst the drainage system should be designed for 30year and 100year flows, guidance suggests filter strips should be designed for a 1 year 30 minute storm, being representative of an appropriate water quality treatment event where the interception of a first flush discharge is of key importance.

Figure 9-12 - Filter strip alongside a road (SuDS Working Party)

9.3.4.1. Filter strips - Dos and Don'ts

A summary of the "Dos" and "Don'ts" for filter strip installation can be seen in the table below:

Table 9-3 – Filter Strips - Dos and Don'ts

Do	Don't
Allow one full growing season for vegetation to establish before allowing run-off across or provide erosion protection	Install unless strip is at least 1 m above the ground water level if infiltration is likely to occur
Use in conjunction with other SuDS or as part of a SuDS management train	Install where pedestrian traffic is likely to occur
Provide a drop of at least 50mm from the pavement edge to the filter strip	Install at a steeper gradient than 1/20
Avoid point inflows into the filter strip which will enable erosion of the grassed area	Compact the soil – reducing infiltration

Figure 9-13 – Filter strip showing need of maintenance

9.3.5. Construction

As with all SuDS components, filter strips need to be protected during construction of the surrounding site. Vehicles should be prevents from trafficking across the strip to ensure the permeability of the area remains high. The grassy finishing needs to be maintained during establishment, whether seeding or turf. Irrigation will be required particularly in drier periods.

9.3.6. Maintenance

The maintenance of filter strips can be cost effective and relatively straightforward. The table below summarises the types of maintenance and indicates their likely frequency. It should be noted that maintenance activities such as grass cutting should not be carried out if the ground is wet as this will, aside being a health and safety issue, damage the ground and vegetation as well as potentially compacting the ground.

Table 9-4 – Filter strip maintenance activities

Maintenance Schedule	Required Action	Estimated Frequency	Maintenance effort
Regular Maintenance	Litter and debris removal.	Monthly for 1st year, then three times per year	For surface area of less than 1000m², assume 1 site visit with 3 men assuming 1 light van, mower and ancillary equipment.
	Grass cutting – to retain grass height within specified design range of 75-100mm, not to exceed 150mm, with cuttings to be left on site	Monthly for 1st year, then three times per year	Included within above site visit
	Manage other vegetation and remove nuisance plants.	Monthly for 1st year, then three times per year	Included within above site visit
	Check for poor vegetation growth due to lack of sunlight or dropping of leaf litter, and cut back adjacent vegetation where possible.	Annually	Included within above site visit
	Inspect gravel diaphragm trench upstream of filter strip for clogging.	Half yearly	Included within above site visit
	Inspect silt accumulation rates and establish appropriate removal frequencies. Where silt has accumulated remove an oblique divot along the hard edge to reinstate flow	Half yearly	Included within above site visit
	Remove silt and spread locally outside design profile and reinstate surface	Half yearly	Included within above site visit
	Inspect filter strip surface to identify evidence or erosion, compaction, ponding, sedimentation and contamination (e.g. soils).	Half yearly	Included within above site visit
	Check flow spreader and filter strip surfaces for even gradients.	Half yearly	Included within above site visit
Occasional Maintenance	Repair erosion or other damage by re-turfing or reseeding.	Every 5 years	Included in occasional maintenance site visit below
	Re-level uneven surfaces and reinstate design levels.	Every 5 years	Included in occasional maintenance site visit below
Reactive Actions	Re-seed areas of poor vegetation growth. Re-turfing and levelling. Alter plant types to better suit conditions, if required.	Every 5 years	For filter strip area up to 1000m², assume 1 site visit with 3 men, 1 light van, small excavator and ancillary equipment.
	Scarify and spike topsoil and reinstate design levels.	As required	Included within above site visit
	Remove and dispose of oils or petrol residues using safe standard practices.	As required	Included within above site visit

9.4. Ponds

9.4.1. What is a pond?

SuDS ponds are permanent bodies of open water, which can be used to attenuate and store surface water runoff in storm conditions. They are typically planted with marginal, emergent and aquatic plants, and may be stocked with fish, and provide an element of water quality treatment (dilution and detention) of the runoff before ultimate discharge. SuDS ponds differ to non-SuDS ponds in as much as they have a storage capacity above the normal water volume, and also contain features designed to improve health and safety over natural ponds, such as defined edges.

A retention basin is a SuDS feature akin to a pond. The basin holds water permanently, although may empty during prolonged dry weather. The design of ponds and retention basins are very similar.

9.4.2. How do they work

The pond receives water from other SuDS features, such as swales, and regulates the outflow using a control, such as a weir or orifice. Water is attenuated, whereby the outflow is limited by a control and the excess inflow is accommodated by a rise in water level.

Ponds provide valuable biodegradation of hydrocarbons by allowing microorganisms in the water column to feed and pull in oxygen from shallow water. They should, however, receive free inflow as free as practicable from sediment to minimise deposition and ongoing maintenance issues.

The inclusion of ponds in a SuDS installation will provide aesthetic benefit to areas of public use, and habitat for local species. They may also add to the economic value of a site.

Figure 9-14 – Site before and after development showing ponds with walkways, seating and information boards

9.4.3. Design

- have a permanent pool volume for water quality treatment
- provide temporary storage volume for flow attenuation
- create a sediment forebay to capture suspended solides or use pre-treatment
- have a length to width ratio of between 3:1 and 5:1
- use a minimum depth in open water of 1.2m
- use a maximum depth in the permanent pool of 2m
- have side slopes / banks less than 1 in 3

Figure 9-15 - Key design criteria for ponds

9.4.3.1. Site and planning considerations

Soil conditions, topography and site characteristics are all factors to consider when including a pond into a development site. Sites with steep topography may not be suitable for ponds and the storage of water, due to the need for sizeable embankments.

Residential housing, and other developments, with large impermeable surface areas are good examples of sites, which can benefit by sub-division into smaller drainage areas and each having the runoff collected in ponds.

Small sites may not be suitable for the inclusion of a large pond. However, small individual collection ponds can be integrated into the landscaping of hard surface areas, and subsequently linked by swales.

Ponds should be easily seen and not hidden from users of the development. This approach reduces the risk of unauthorised or accidental access into the pond and reduces the risk of drowning. However, sites should be chosen to promote the habitat and biodiversity and hence should receive little artificial light from the development at night. The pond location should also avoid the need for tree clearance during construction.

To improve the ecological connectivity of the ponds, as wildlife havens, with the rest of the development and the environs, safe paths for wildlife should be included.

9.4.3.2. Design considerations

Ponds are very versatile forms of SuDS and can be integrated with landscape features. There may be a need for hard edges in urban landscapes, whereas large green open spaces benefit from soft lines and organic shapes mimicking natural habitats. Shallow ponds will reduce land take and every effort should be made to keep inlets close to ground level. Amenity and safety are key considerations in both the location and design of ponds.

The pond/s should be placed last in the overall SuDS treatment train to ensure they only receive relatively clean water. Source control is a key part of the treatment train and incorporating such will ensure the pond only receives a controlled inflow – so reducing turbulence, turbidity and erosion in the feature.

Ponds should provide both wet and dry areas with a range of moisture conditions, to store water. This can be achieved by providing a variation in the pond shape and depth – for example by having shallow pools.
Sites with high permeability soils may need lining to prevent loss of water through infiltration and thus create a permanent pond area. To this effect, the pond could be lined and preference is always for a natural puddle clay or similar lining. Man-made liners can be used if clay is not a viable option. Consideration an infiltration pond could be made in such circumstances too, subject to ground water source protection criteria. See Section 10.4 on detention and infiltration basins.

A series of linked ponds may provide greater removal of pollutants. This type of design can also increase biodiversity, as well as providing larger storage volumes, and be more readily accommodated within the site.

Figure 9-16 – Typical SuDS pond

The key design consideration are:

- The pond should be placed last in the overall SuDS treatment train.
- Measures are required to remove sediment from the inflows to a pond. This could be through construction of a forebay although preference in Gloucestershire is for source control through the use of filter strips.
- Access for plant to undertake de-silting works should be included in the design where necessary.
- The inlet velocity of the pond should be restricted to less than 0.5m/s which may be achieved by incorporating a forebay.

- The pond size should contain between 1 and 4 times the volume required for treatment although this is not as important within an overall SuDS treatment train. This treatment volume is defined in the CIRIA SuDS manual C697.
- The pond should be sized to account for the required site attenuation volume at that point in the SuDS train.
- The shape of the pond should be designed to allow a long retention time and prevent inlet water from diverting quickly to the outlet. A rule of thumb is to have the length 4 or 5 times the width.
- Where pond liners are used, they should be sandwiched between a geofabric or sand protection, and be at least 300mm below bed level.
- The pond should be constructed with an outlet to allow the passage of runoff from everyday rainfall though the pond at the designed outfall level (permanent water level), subject to the permitted outflow rates. To prevent blockage of the overflow, it should be formed from a reverse slope pipe or perforated control tube
- The pond should be constructed with an emergency overflow, to prevent flooding from the pond during extreme weather. This should be at least 600mm above the permanent water level but below the lowest level around the pond, and below the lowest ground level upstream of the pond.
- The pond should be constructed with a drain, to allow the pond to be drawn down for maintenance, or repairs.
- Pond should have a 1 in 3 bank slope or less with a 1m wide dry flat landing at the water's edge.
- A 1m wide level wet bench should be provided some 150mm below the permanent water level.
- The water in a pond should not be greater than 2m deep.
- Low nutrient soils should be used in the pond and its margins.

Figure 9-17 – SuDS pond showing inlet on far bank

The following design parameters are suggested by CIRIA in the SuDS manual updates.

Parameter	Pond
Width of aquatic bench	Greater than 1m
Slope of aquatic bench	1 in 15
Depth of aquatic bench	450mm
Width of safety bench	Greater than 3.5m
Slope of safety bench	Less than 1 in 15
Maximum rise in water level for 1 in 100 year event	1.5m
1 in 30 year event should have a size of	Treatment volume (Vt)

Table 9-5 – Other pond design criteria (CIRIA 2013)

9.4.3.3. Ponds - Dos and Don'ts

The following table summarises the key issues for inclusion of ponds in your SuDS scheme.

Do	Don't
Native species of local provenance will be favoured and should be appropriate for the individual conditions provided by each feature. Ponds to be planted to enhance biodiversity. Do contact the Gloucestershire Wildlife Trust to aid planting regimes.	Non-native species may be considered in the more formal or urban settings but care must be taken not to introduce invasive species to the pond or wetland system. A planting list is provided at the end of this section.
Where appropriate the species mix should aim to create habitats that contribute to those contained in the Gloucestershire Nature Map, along with regional and national Biodiversity Action Plans.	Where possible avoid areas with artificial lighting when locating wetland features.
Wetlands should be designed with safety in mind.	Don't hide wetland features away, make them communally visible and a central part of development.
Always make sure Wetlands SuDS are linked with other SuDS features, wetlands allow vegetation and other organisms to remove nutrients, soluble metals and oil based pollution	Ensure that new SuDS features are located in close proximity to, but not directly connected to, existing aquatic/wetland/ marginal features to minimise their deterioration.
Where possible retain all existing vegetation and surrounding trees.	

Table 9-6 – Summary of pond considerations.

Figure 9-18 – Conceptual layout of ponds in a chain

9.4.4. Suggested planting list

It is recommended that a qualified ecologist with experience of aquatic and wetland habits is contracted to advise on species to be used on SUDs features. If this is not possible then the list at the bottom of this page provides plant species suitable for use in Gloucestershire SuDS pond features. This list is not exhaustive and the exact choice should relate to site-specific conditions.

Where possible, designs should contain a range of plant communities and habitats across a range of moisture regimes. Once the location and site conditions have been discussed we recommend discussion with ecologists or specialist suppliers of British wild flowers and grasses, who will be able to advise on appropriate natural plant species lists to suit specific site requirement and function.

A planting mix, identified as suitable for pond planting, is suggested here order to prevent out competition by the more vigorous plant species (from CIRIA C697, 2007).

- 10% Agrostis stolonifera (Creeping bent grass)
- 10% Apium nodiflorum (Fools water cress)
- 20% Filipendula vulgaris (Meadowsweet)
- 10% Glyceria fluitans (Floating sweet grass)
- 10% Myosotis scorpiodies (Water forget-me-knot)
- 10% Mentha aquatic (Water mint)
- 10% Nasturtium officinale (Watercress)
- 10% Persicaria amphibian (Amphibious bistort)
- 10% Veronica beccabunga (Brooklime)

The edges of the forebay and main pond should be seeded as amenity grassland with a wildflower component.

9.4.5. Construction

The construction of ponds will need to be managed to ensure that no sediment enters the pond during the works. The banks of the pond should not be rolled or consolidated but ripped prior to layering with topsoil to ensure adequate root penetration.

Construction runoff must be addressed to prevent erosion of the pond banks and during the establishment stage of the planting – this will ensure the plants have time to take a hold and protect the formation into the future.

9.4.6. Maintenance

The management of ponds and retention basins will involve grass and vegetation cutting for access and visual amenity. All outlets and overflows should be frequently inspected and cleaned to ensure their efficient operation.

It is common for smaller ponds to suffer from algal blooms during the summer. This risk can be minimised by reducing the amount of fertiliser used in the surrounding landscaping, and where necessary skimming off the floating mass. Most ponds naturally overcome the algal bloom as the pond establishes.

Ponds and retention basins may need intermittent maintenance to remove sediment and excess vegetation. This should be carried out in stages to minimise effects on the wildlife inhabiting the pond/ basin area.

The period between September and November is best time for pond maintenance as it is outside the newt breeding and bird nesting season, and will have minimal impact on water voles.

Figure 9-19 – Pond in need of maintenance

The table overleaf summarises the maintenance activities and the likely frequency:

Table 9-7 – Pond maintenance activities

Maintenance Frequency	Actions Required	Maintenance Frequency	Maintenance effort
Regular maintenance	Litter and debris removal	Monthly	For surface area of less than 100m², assume 1 site visit with 3 men assuming 1 light van, mower and ancillary equipment
	Amenity grass 35-50mm for access, paths and visual requirements	As required	Included within above site visit
	Grass cut to pond edges, access and overflows 75-100mm and not to exceed 150mm	Monthly or as required	Included within above site visit
	Wetland, meadow or rough grass cut at 50mm and remove to wildlife or compost piles	Annually or as required	Included within above site visit
	Cut pond vegetation if required and no more than 30% 100mm above pond base and remove to wildlife or compost piles	Annually or as required	For pond area up to 100m², assume 1 site visit with 3 men, 1 light van, small excavator and ancillary equipment.
	Inspect and clear inlets, outlets and control structures	Monthly	Included within above site visit
	Remove sediment from forebay structures	Annually	Included within above site visit
Occasional (e.g. Seasonal)	Review silt accumulation remove and site apply or take off site if necessary	Every 5 years	For pond area up to 100m², assume 2 site visits with 3 men, 1 light van, small excavator and ancillary equipment.
	Removal of tree or shrub growth within 5m of pond edge	Every 5 years	Included within above site visit
	Clearance of established Common Bulrush (Typha latifolia) 25% at a time on a yearly cycle	Annually	
Remedial works and Repairs	Repair or replace inlets, outlets or control structures to design detail	As required	2 site visits with 3 men, 1 light van, small plant and ancillary equipment.

9.5. Detention and Infiltration Basins

9.5.1. What is a detention and infiltration basin?

Detention basins are dry flat areas with shallow depressions used for the temporary storage of excess storm water. In a storm event water accumulates in the depression and then is either slowly discharged to the next SuDS component or to a receiving watercourse.

An infiltration basin is a similar feature, although the detained water is left to soakaway to ground by infiltration through the base and sides of the feature. Thus there is a site requirement to ensure that the ground is suitable for infiltration.

Detention and infiltration basins provide a useful stage in pollution control. The slowing of flows allows settlement of suspended solids and allows biological uptake of pollutants by plants, algae, and bacteria.

Figure 9-20 – Detention pond - empty

9.5.2. How do they work?

The dry detention basin receives water from other SuDS features, such as swales, and regulates the outflow using a control, such as a weir or orifice. Water is attenuated in the short term, whereby the outflow is limited by a control and the excess inflow is accommodated by a rise in water level.

For the infiltration basin, water is allowed to drain naturally into the ground. This can be encouraged by the inclusion of a drainage trench or stone through the centre of the basin, or by providing a formal stone drainage blanket across the base.

The benefit of a detention or an infiltration basin is the reduction in the flow rate and the volume of water downstream. The inclusion of detention and infiltration basins in a SuDS installation can provide aesthetic benefit to public areas as well as area for children's play, informal sport, social space, visual quality and habitat creation.

9.5.3. Design

- have a detention volume to manage the design storms using a contrained outflow
- have a length to width ratio of 2:1
- have side slopes / banks less than 1 in 3 for maintenance and safety reasons
- bioretention or small wetland pools are desirable at the outlets for enhanced pollution control
- need effective pre-treatment to remove sediments before reaching the infiltration area
- design to infiltrate the water quality treatment volume as a minimum
- do not use infiltration where groundwater is vulnerable to pollution or on contaminated sites

Figure 9-21 - Key design criteria for detention and infiltration basins

9.5.3.1. Site planning and considerations

Groundwater depth and conditions should be considered when assessing site suitability.

Sites with variable topography may not be appropriate as large retaining structures may be necessary to detain the water.

Detention basins are best suited to clay soils, because the water is not rapidly soaked up – whereas the infiltration options are better suited to the more permeable areas.

Figure 9-22 – Detention pond - full

9.5.3.2. Design Considerations

Pollution control is best achieved by increasing the time in residence. Detention and infiltration basins are designed to store water temporarily.

Basins should be used as part of a series of pollution control measures. The distances between the inlet and outlets should be made as long as possible to slow the through-flow and maximise the benefits of improved water quality and a reduction in discharge.

Additional environmental interest can be provided by allowing small, shallow, ephemeral bodies of water inside the normally dry basin.

The following design parameters should be considered:

- The depth of water for a 1 in 100yr event should be less than 600mm.
- The designed storage must consider flood risk.
- Sediment should be intercepted at source before it can enter the detention basin.
- Side slopes of the detention basin should be in keeping with our maintenance requirement requiring slopes more shallow than 1:3. This will also help to reduce flow speed of any incoming overland flow and reduce erosion risks around the basin.
- The longitudinal slope of the basin must be less than 1 in 40, ideally 1 in 100, to maximise detention and opportunities for infiltration. Tolerances on the falls should be carefully controlled where damp patches are deemed undesirable.
- Geofabric linings can be used to reduce the risk of erosion on the side slopes.
- Erosion at the inlet and outlet can be minimised by reducing the flow velocities into and out of the basin. The use of concrete or stone baffles, or forebays, can be used to further decrease risk of erosion in these areas and strengthen the control structures for high flows, and any incoming channel or pipe should permit free discharge into the basin at the designed storage level.
- To facilitate infiltration in semi permeable soils, drainage trenches can be constructed in the bottom of basins – see Section 10.6 on Filter Drains.
- The dimensions of the basin should ideally be 2 to 5 times long as they are wide, to increase the opportunity for settlement and infiltration.
- A controlled outlet should be installed to regulate the discharge from the basin to that determined by the quantity and volumetric requirements. The outlet should be at, or slightly lower than, the invert level of the basin to ensure effective drainage and that the basin remains dry in fine weather.
- The outlet should incorporate an overflow to act in times of extreme rainfall or blockage of the outlet.
- Filter fabric membranes should be used to wrap the infiltration trench, or blanket.
- A high permeability topsoil should be used to encourage infiltration from the surface.
- Planting within the basin should be selected to cope with inundation and submergence and typically be of wildflower and meadow grass. The maximum water depth should be 600mm and the possibility for submergence over 48 hours accounted for.

- Warning sign must be provided around any detention basin, as the usually dry feature may be mistaken for a permanent amenity area as opposed to a drainage feature
- A micro pond at the outlet "can be used to enhance treatment and avoid a muddy area at the outlet providing bio-diversity interest with native planting".

9.5.3.3. Detention and infiltration basins - Dos and Don'ts

The following table summarises the key issues for the inclusion of detention and infiltration basins in your SuDS scheme.

Table 9-8 – Summary of basin considerations.

Do	Don't
Consider adding an ephemeral wet area to increase biodiversity.	Fence off the basin – designed well it will not be an unsafe place.
Include a forebay to promote and settlement in a controlled area.	Allow point discharges into the basin without the use of a forebay, diffuser or spreader.
Design the basin to accommodate amenity uses for the owner/ occupiers of the site.	Compact the soils along the base of the basin as this will reduce the ability of water to infiltrate.
Always make sure detention and infiltration basins are linked with other SuDS features.	Use where the base on the feature will be within 1m of the normal groundwater level.
Where possible retain all existing vegetation and surrounding trees.	Construct as the last SuDS feature on your development drainage system.

9.5.4. Construction

To minimise the risk of wet areas forming in the basin, the topsoil should have permeability similar to, or greater than, that of the sub-soil.

During construction of a basin, in particular an infiltration basin, care must be taken to avoid over compaction of the sub-surface and the top soil. At that time, the excavated basin should be protected to minimise the risk from erosion and to prevent sediment deposition that may blind the infiltration components.

Figure 9-23 – Example detention basin with infiltration trench and micro-pool

9.5.5. Maintenance

Maintenance requirements for detention and infiltration basins ponds are similar to those of swale systems.

Regular grass cutting will be required to keep the meadow grass sward at around 100mm high. Longer grass is likely to lodge flat and afford reduced filtration treatment on subsequent storms. Very short grass may result in erosion and the movement of sediment into the downstream system.

There may be a requirement for intermittent silt removal within basins.

The table overleaf summarises the maintenance activities and the likely frequency:

Table 9-9 – Detention basin maintenance activities

Maintenance Frequency	Actions Required	Maintenance Frequency	Maintenance effort
Regular (e.g. Monthly)	Litter and debris removal from site. Clear organic materials in the autumn.	Monthly for 1st year, then three times per year	For surface area of all SuDS less than 1,000m², assume 1 site visit with 3 men assuming 1 light van, mower and ancillary equipment.
	Grass cutting on sides and bed of the basin to 35-50mm lengths except access paths which require 75-100mm length	Every 2 months in the growing season.	
	Inspect and if necessary clear inlet, outlet and overflow openings, and clear if required	Monthly with litter removal	Included in above site visit
	Inspect inlets and facility surface for silt accumulation. Establish appropriate silt removal frequencies.	Every 6 months	Included in above site visit
	Pruning and trimming of trees.	Every 2 years	Included in above site visit
	Spiking, scarifying and thatch removal.	Every 3 years (when mulching)	Included in above site visit
	Inspect infiltration surfaces for ponding. Record dewatering time of the facility to determine if maintenance is necessary	Three times per year	Included in above site visit
Occasional (e.g. Seasonal)	Remove silt from basin outlet and invert	As required	
	Weeding	As required (probably annually)	Included in above site visit
Remedial works and Repairs	Remove and replace sacrificial geofabric and stone layers to de-silt the surface of the infiltration trench.	As required	Detention area up to 1000m², assume 1 site visit with 3 men, 1 light van, small excavator and ancillary equipment.
	Inspect and repair any damage to the formal inlets and outlets from the basin	As required	
	Sediment removal and rehabilitation. Removal of damaged or silt covered vegetation to a depth 50mm below original design level.	Every 5 years	Detention area up to 1000m², assume 1 site visit with 3 men, 1 light van, small excavator and ancillary equipment.
	Treatment of diseased trees.	Three times per year, if required	Included in above site visit
	Treatment and restoration of eroded areas.	Three times per year, if required	Included in above site visit
	Re-turfing.	Three times per year, if required	Included in above site visit
	Reinstatement of design levels, restoration or improvement of infiltration and silt removal.	Three times per year, if required	Included in above site visit

9.6. Wetlands

9.6.1. What is a Wetland?

Wetlands are open areas of shallow water designed with a primary function to treat water quality and provide biodiversity rather than provide temporary storage for excess water.

The use of wetland features through SuDS provides an opportunity to replace lost landscape features and habitats and we expect new wetlands to be planted to enhance biodiversity where possible.

9.6.2. How do they work?

Wetlands should always be linked with other SuDS systems so that as much sediment as possible can be removed prior to reaching them. As such, the wetland feature should be the last stage in the overall SuDS treatment train.

In order to function well upstream source control elements should address most of the storage and treatment first allowing removal of sediments.

Wetland features work because water flowing slowly through a wetland feature has a high residence time (the time water takes to travel across the feature). This allows vegetation and other organisms to remove nutrients, soluble metals and oil based pollution. In order to work successfully a good supply of oxygen is required within the feature, so permanent water must be shallow to enable oxygen to reach the bottom of the wetland.

Generally speaking, multiple smaller wetland features can provide better biodiversity and are potentially easier to maintain.

As wetland features may be located within areas of public open space they should be designed to be visually attractive as well as providing wildlife habitat. They also need to be safe, given the water will be shallow, appropriate warning notices rather than fencing is considered appropriate.

The location of wetland features in a development should be carefully considered and it should be linked to wildlife corridors.

In the urban setting, wetlands features should be located so as to be communally visible. Therefore ensuring these features are a valued part of a development. Locating wetlands away from artificial light will improve the value of the feature to foraging bats.

In general, the primary purpose of wetlands designed as SuDS is water quality treatment. Secondarily they can also commonly be designed to support amphibians, particularly great crested newts.

Where possible native trees and vegetation should be retained (although we stipulate no trees within 5m of a SuDS feature). A suggested planting list is provided at the end of this section.

Chapter 18 of the CIRIA SuDS manual (CIRIA 2007) provides detailed information on design and maintenance of wetland features. Wetland design should be a combination of deep and shallow areas (<2m depth) with a length: width ratio greater than 3:1 and shallow slopes.

9.6.3. Design

water quality treatment volume is provided

provide temporary storage volume for flow attenuation

create a sediment forebay to capture suspended solids or use pre-treatment

have a length to width ratio of over 3:1

have a combination / mosaic of shallow and deep areas, upto 2m deep

ensure there is a continuous baseflow through the wetland

have slopes / banks less than 1 in 3

Figure 9-24 - Key design criteria for wetlands

9.6.3.1. Design considerations

It is important to consider the design and implementation of wetland construction features in order to prevent common practical problems.

The following practical tips for implementation should prevent some common problems:

- Algal blooms may occur if excessive use of fertiliser occurs in the surrounding landscape, this cannot be controlled easily, but blooms should disappear in time.
- Side slope gradients should not exceed 1:3; with steeper gradients soil slippage is more likely to occur which potentially leads to exposed pond liners where used. Dry bench should have minimum width of 1m, with wet bench minimum 1m wide.
- Where pond liner is used ensure a minimum of 300mm of stable soil covers liner.
- By managing construction runoff, the build-up of silt within wetland features can be prevented, so ensuring the wetland is 'clean' at the start of the defects period. A sediment silt trap will be required to intercept silt unless source control measures are in place
- If water is not held sufficiently within the wetland feature because of permeable soils, a clay subsoil, carefully compacted over the base of the feature or use of a liner will help.
- Where water flows into wetland features at too great a velocity (likely as a result of missing or inappropriate upstream source control) erosion may occur at the inlets and banks.
- If erosion is problematic, biodegradable erosion control mats can be employed.
- Weed killer should not be used prior to construction, as this will promote rapid establishment of local vegetation preventing erosion.
- Excessive tracking of machinery and compaction of soils will lead to poor establishment of marginal plants due to creation of anaerobic conditions.

Table 9-10 – Requirements for ponds and wetlands (CIRIA, 2013)

Parameter	Wetland
Length to width ratio	Greater than 3 to 1
Maximum depth of permanent water	2m
Maximum side slopes	1 in 3
Width of aquatic bench	Greater than 1m
Slope of aquatic bench	1 in 15
Depth of aquatic bench	450mm
Width of safety bench	Greater than 3.5m
Slope of safety bench	Less than 1 in 15
Maximum rise in water level for 1 in 100 year event	1.5m
Wetland mosaic – water depths/areas	Maximum of 20% of the water area greater than 1m; 30% is the water area is 0.5m to 1m deep and 50% where water area is 0m to 0.5m deep
1 in 30 year event should have a size of and a maximum water velocity of	Velocity less than 0.1m/s

9.6.3.2. Wetland - Dos and Don'ts

The following table summarises the key issues for the inclusion of wetlands in your SuDS scheme.

Table 9-11 – Wetland Dos and Don'ts

Do	Don't
Native species of local provenance will be favoured and should be appropriate for the individual conditions provided by each feature. Wetlands to be planted to enhance biodiversity. Do contact the Gloucestershire Wildlife Trust to aid planting regimes.	Non-native species may be considered in the more formal or urban settings but care must be taken not to introduce invasive species to the pond or wetland system. A planting list is provided at the end of this section.
Where appropriate the species mix should aim to create habitats that contribute the Gloucestershire Nature Map, along with regional and national Biodiversity Action Plans.	Where possible avoid artificial lighting when locating wetland features.
Wetlands should be designed with safety in mind.	Don't hide wetland features away, make them communally visible and a central part of development.
Always make sure Wetlands SuDS are linked with other SuDS features, wetlands allow vegetation and other organisms to remove nutrients, soluble metals and oil based pollution	To minimise deterioration of existing aquatic/wetland/ marginal features ensure new SuDS features are located in close proximity but are not directly connected.
Where possible retain all existing vegetation and surrounding trees.	

9.6.3.3. Suggested planting list

It is recommended that a qualified ecologist with experience of aquatic and wetland habits is contracted to advise on species to be used on SUDs features. If this is not possible then the list below provides a species list which provides a generic idea of planting suitable for Gloucestershire SuDS wetland/pond features. This list is not exhaustive and the exact choice should relate to site-specific conditions.

Where possible designs which try to create a range of plant communities and habitats across a range of moisture regimes are favourable. Once the location and site conditions have been agreed we advise discussion with specialist suppliers of British wild flowers and grasses who will be able to advise on appropriate natural plant species lists to suit specific site requirement and function.

CIRIA (2007) provides guidance on the planting mix and relative proportions of vegetation for the forebay areas of wetlands. This is the same as identified as suitable for Swale planting. The following planting mix is recommended for the wetland areas, indicative proportions are suggested in order to prevent overgrowth by certain particularly vigorous plant species.

- 10% Agrostis stolonifera (Creeping bent grass)
- 10% Apium nodiflorum (Fools water cress)
- 20% Filipendula vulgaris (Meadowsweet)
- 10% Glyceria fluitans (Floating sweet grass)
- 10% Myosotis scorpiodies (Water forget-me-knot)
- 10% Mentha aquatic (Water mint)
- 10% Nasturtium officinale (Watercress)
- 10% Persicaria amphibian (Amphibious bistort)
- 10% Veronica beccabunga (Brooklime)

The edges of the forebay and wetland should be seeded with amenity grassland with a wildflower component.

9.6.4. Construction

The construction of wetlands will need to be managed to ensure there is no sediment build up in the wetland during the works. Conversely, the banks of the wetland should not be rolled or consolidated but ripped prior to layering with topsoil to ensure adequate root growth of the vegetation.

Runoff during construction must also be addressed to prevent erosion of the banks and during the establishment stage of the planting – this will ensure the plants have time to take a hold and protect the formation into the future.

9.6.5. Maintenance

Cutting/strimming is only likely to be required intermittently (maximum annually) and should be carried out between September to November to minimise impact on wildlife. Where appropriate, cuttings should be removed to temporary wildlife piles. Where SuDS wetlands may contain heavy metals, the placement of cut and dredged materials could lead to leaching of pollutants. Therefore, wildlife piles should only be created on sites with a low pollutant risk.

Where possible the habitat should be maintained as a mosaic, typically it is suggested around 25% of reed bed is removed annually, this will avoid the transfer of pollutants from dead plant matter to silt being remobilised and will also allow the wetland feature to be maintained.

Ideally measures should already be in place to remove sediments upstream, however, over time silt accumulates. Should it accumulate more than 150mm in the base of a wetland, removal may be required. It is recommended not more than 30% of the pond or wetland area at any one time is removed. Removal should not encroach on the subsoil layer and should retain as much representative vegetation as possible.

Where possible wetland features should be designed so that special machinery is not required to undertake maintenance we also require the following:

- any drainage asset that requires maintenance must have suitable vehicular access;
- Gloucestershire County Council's Ecology Officer should be consulted on proposed wetlands and above ground attenuation; and
- trees cannot be planted within 5m of any surface water drainage unless a suitable and approved root barrier method used.

The table overleaf summarises the maintenance activities and the likely frequency:

Table 9-12 – Wetland maintenance activities

Maintenance Frequency	Actions Required	Maintenance Frequency	Maintenance effort
Regular maintenance	Litter and debris removal	Monthly	For surface area of less than 100m², assume 1 site visit with 3 men assuming 1 light van, mower and ancillary equipment
	Amenity grass 35-50mm for access, paths and visual requirements	As required	Included within above site visit
	Grass cut to wetland edges, access and overflows 75-100mm and not to exceed 150mm	Monthly or as required	Included within above site visit
	Meadow or rough grass cut at 50mm and remove to wildlife or compost piles	Annually or as required	Included within above site visit
	Cut wetland vegetation if required and no more than 30% 100mm above wetland base and remove to wildlife or compost piles	Annually or as required	For wetland area up to 100m², assume 1 site visit with 3 men, 1 light van, small excavator and ancillary equipment.
	Inspect and clear inlets, outlets and control structures	Monthly	Included within above site visit
Occasional (e.g. Seasonal)	Remove sediment from forebay structures	Annually	Included within above site visit
	Review silt accumulation remove and site apply or take off site if necessary	Every 5 years	For wetland area up to 100m², assume 2 site visits with 3 men, 1 light van, small excavator and ancillary equipment.
	Removal of encroaching wetland vegetation as required to meet any specie design objectives	Every 3 years	For wetland area up to 100m², assume 2 site visits with 3 men, 1 light van, small excavator and ancillary equipment.
Remedial works and Repairs	Repair or replace inlets, outlets or control structures to design detail	As required	2 site visits with 3 men, 1 light van, small plant and ancillary equipment.

9.7. Filter drains

9.7.1. What is a filter drain?

Filters drains (also referred to as filter trenches or French drains), are linear excavated trenches which are backfilled with graded rubble or stone. They are an engineered SuDS option to both convey water and promote infiltration.

With a surface appearance of a stone strip, they are not always as aesthetically pleasing as some SuDS alternatives.

9.7.2. How do they work?

The purpose of this type of SuDS solution is to capture overland flows and store them until the water can naturally infiltrate into the surrounding ground. As such, there is a site requirement to ensure that the ground is suitable for infiltration.

Filter drains are effectively a type of temporary subsurface storage and infiltration soakaway. In addition to their role in allowing infiltration of water, if correctly designed, filter drains can be used to convey water along the SuDS train from one area to another, i.e. capturing water and transporting it to a retention pond further away from the source.

Figure 9-25 - Filter drain protected by grass filter strip (Susdrain)

Water captured by the filter drain can either infiltrate gradually into the subsoil or discharge to another structure at a controlled rate via a perforated pipe in the base of the drain.

The stone fill material in the filter drain allows an element of temporary storage, typically up to a volume of 30%.

The filter drain will also provide an element of water quality treatment through biodegradation of pollutants. Certain filter drains are also known as Treatment Trenches.

Figure 9-26 - Filter drain (SuDSwales)

9.7.3. Design

Figure 9-27 - Key design criteria for filter drains

- excavated trench 1m to 2m deep filled with stone aggregate
- needs effective upstream pre-treatment to remove sediments
- infiltration not to be used where groundwater is vulnerable to pollution, or for contaminated sites
- needs observation points and access to any perforated pipework

9.7.3.1. Design considerations

Filter drains are a beneficial part of the SuDS system and are commonly used next to new roads because of their small space requirements and no surrounding drainage infrastructure is required.

The inclusion of exposed stone material in the filter drain means that their placement should be considered carefully, and may only be suitable in lightly trafficked areas, away from dense population concentrations. They can be used inside a grass swale to infiltrate low flow rates, the peak flows being transported by the swale. Consideration of maintenance of any surrounding grassed areas should be made to ensure the filter drain does not affect mowing operations.
Filter drains are susceptible to blockage with debris and

sediment, which clogs the voids between the stones – reducing the available storage volume – as well as blocking perforated pipes which can be used to transport water around the SuDS network. Whilst these drains are designed to capture sediment, they should be protected (e.g. with a filter strip upstream) to prevent fine material entering the drain and have a geofabric wrapped around the trench to prevent the ingress of fines.

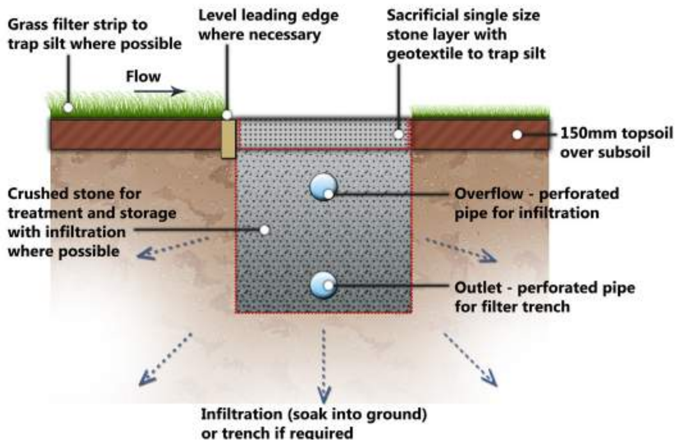


Figure 9-28 - Typical Filter drain cross-section detail

Some of the main aspects to consider are included below:

- Due to the filter drain's susceptibility to blockage from fine material, some form of sediment capture is required upstream of the drain, particularly on point discharges (e.g. filter strip or silt traps in feeding pipes).
- The edge of the filter drain trench should be level with the surrounding land to encourage overland flow into it.
- A pipe installed at a low level in the drain should be included if water transfer along the system is required. This pipe should not be placed at the base of the drain so as to allow some element of infiltration at source and installed with its perforations on underside.
- If designed as an infiltration drain, a high level pipe should be installed as an overflow to an adjoining SuDS feature, in the event that the storage volume is exceeded.
- Vehicular access onto the filter drain should be prevented to avoid damage to, or compaction of the stone fill material.
- Pipework can be minimised to the first and last few metres of the drain to maximise the potential for infiltration. If the pipe work is connecting to a downstream SuDS feature, be aware of potential for material to migrate down the pipe.
- If the filter drain is intended to transfer of water further down the SuDS system, access should be included to allow clearing/rodding of the perforated pipe to enable the clearance of blockages.
- A sacrificial stone layer and geotextile material can be used as a sediment trapping method at the surface of the drain. This element will require monitoring and occasional replacement.
- A grass filter strip can protect the filter drain at source. De-silting can be undertaken to simple trenches with special machinery and good access.
- The filter drain must have suitable vehicular access for maintenance.
- SuDS solutions to be landscaped to reflect nature and existing site context – filter drains might be unsuitable in certain situations.
- Drainage to be designed for 30year and 100year flows, accounting for climate change.

Figure 9-29 - Filter drain leading to pond

Figure 9-30 – Filter drain

9.7.3.2. Filter drains – Dos and Don'ts

A summary of the Dos and Don'ts for filter drain installation is contained in the table below.

Table 9-13 - Filter drains – Dos and Don'ts

Do	Don't
Lay the main perforated pipe within the trench 50mm above the invert level unless infiltrating, in accordance with the relevant pipe bedding detail	Lay at a steep grade to increase the risk of ponding and negative filter gradients.
Only use pipework for the last few metres in treatment trenches where infiltration is preferential	Insert lateral connections at the base of the trench, insert at high level instead
Install an inspection pipe at regular intervals to assess water levels and need for maintenance	Infiltrate where foundations could be effected
Allow lateral inflow from an adjacent impermeable surface	Design the trench so there is a retained body of water greater in depth than 50mm unless infiltrating
Consider silt traps or sediment control device at each inlet and outlet point of SuDS	Use where large sediment loads may be deposited on the paved area surface

9.7.4. Construction

The construction of filter drains will need to be managed to ensure there is no sediment build up in the filter trench (stone) during the works. As such, once filter material is being installed, care should be taken to manage runoff into the trench until the facility is operational.

9.7.5. Maintenance

The table overleaf summarised the types of maintenance and indicates their likely frequency:

Table 9-14 – Filter drain maintenance activities

Maintenance Frequency	Actions Required	Maintenance Frequency	Maintenance Effort
Regular Maintenance	Litter and debris removal from trench surface, access chambers and pre-treatment devices.	Monthly for 1st year, then three times per year	1 site visit with 3 men assuming 1 light van, mower and ancillary equipment.
	Remove weeds on the trench surface.	Monthly for 1st year, then three times per year	included within above site visit
	Inspect inlets, outlets and inspection points for blockages, clogging, standing water and structural damage.	Monthly for 1st year, then three times per year	included within above site visit
	Excavate trench walls to expose clean soils if infiltration performance reduces to unacceptable levels. Replace geo-textiles and clean and replace filter media, if clogging occurs.	Every 5 years	Based on filter drain up to 100m length removal of top layer of gravel, clean and replace. Assume 1 site visit with 3 men, 1 light van, small excavator and ancillary equipment.
	Clear perforated pipework blockages.	As required	included within above site visit
Occasional Maintenance	Remove silt from any treatment features upstream of the filter drain	Annually	included within above site visit
	General de-silting of stone fill material within the filter drain	Every 5 years	Based on filter drain up to 100m length removal of top layer of gravel, clean and replace. Assume 1 site visit with 3 men, 1 light van, small excavator and ancillary equipment.
	Inspect pipes and remove any silt build-up by jetting or another appropriate method	As required	Included within above desilting site visit
Reactive Actions	Remove and replace sacrificial geotextile and stone layers to de-silt the surface of the drain.	As required	Based on filter drain up to 100m length removal of top layer of gravel, clean and replace. Assume 1 site visit with 3 men, 1 light van, small excavator and ancillary equipment.

9.8. Permeable Surfaces

9.8.1. What are permeable surfaces?

Porous surfaces allow water to infiltrate through into the ground rather than draining away from it. Where conditions are appropriate water can then infiltrate directly into subsoil or alternatively be held in a granular sub-base for delayed discharge into another structure. Overflows can be incorporated into the pavement design to ensure surfaces are kept free of water at all times.

Traditional surfaces, used for vehicle or pedestrian areas, prevent water entering the ground beneath, instead causing water to run off into other areas where it is collected in gullies. This is because it is undesirable to allow water into conventional sub-base material.

This traditional design increases the volume and quantity of rainwater leaving the immediate area, ultimately leading to flooding.

Figure 9-31 – Permeable paving in residential areas (Interpave)

Permeable pavements are typically made from block or stone setts and retain the hard surfacing for pedestrians or vehicles whilst permitting rainwater to infiltrate through the surfacing, into the sub-base and eventually soaking into the ground underneath.

Formerly called porous paving, where water infiltrated through the blocks, permeable paving requires the infiltration through the joints in the surface.

The current planning 'Permitted Development' rules aim to apply SuDS techniques to new or replacement paving around existing homes and various non-domestic buildings. They take away permitted development rights from most new or replacement paving, unless it is permeable paving or drains water onto a permeable area on the property.

9.8.2. How do they work?

There is a growing choice of concrete blocks and flags available, designed specifically for permeable paving. Essentially they have the same performance as conventional precast paving. Various shapes, styles, finishes and colours are available allowing design freedom.

The difference is enlarged joints created by larger than conventional spacer nibs on the sides of each unit. These joints are subsequently filled with a joint filling material specific to each product, which is an angular aggregate, not sand. This arrangement ensures that water will continue to pass through the joints over the long-term. It is fundamentally different to porous paving. Permeable pavements offers a major benefit in modern urban design, enabling accessible shared surfaces to be created without the need for cross falls, channels or gullies, while still avoiding standing water.

Permeable pavements are now widely used although often not constructed correctly. The brick units are laid with reasonable sized joints, such that rainwater can readily percolate through the joints and into the material below.

Figure 9-32 - Permeable pavement in a car park

There are various unit manufacturers for permeable pavements, each with unique block shapes to aid laying. The specific laying pattern will aid the percolation of water from the surface.

Where conditions are appropriate water will infiltrate directly into subsoil or could alternatively be held in a granular sub-base for delayed discharge into another SuDS structure. Infiltration rates of 1800 to 2400 l/s per hectare have been achieved for permeable paving. Given a 1 year storm might generate 100 l/s per hectare, the benefits of permeable paving are obvious. Permeable paving can therefore also handle additional runoff from roof drainage, and requires no additional land-take.

Depending upon design and SuDS system considerations it is possible to link permeable paving to other SuDS options and to move water volumes around the SuDS system.

Permeable pavements provide excellent opportunities for source control, tackling rainfall where it lands. They are also exceptional at treating the first flush runoff in terms of water quality, and then providing interception storage where quantity and volume control are required.

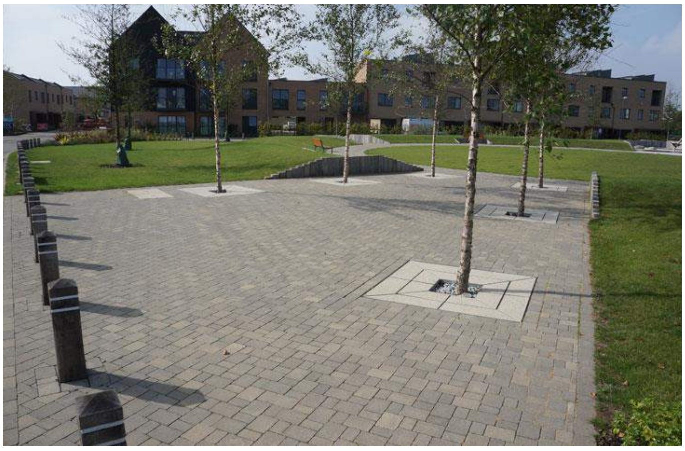


Figure 9-33 – Permeable paving (Interpave)

Permeable surfaces have a medium to high diffuse pollutant removal potential and can reduce surface spray from roads, which in turn reduces pollutants washed-off the underside of vehicles. The pollutants are held below the surface, and degrade slowly and (in infiltrating pavements) can be filtered down through into the subsoil.

There are a variety of permeable surfacing materials available.

9.8.3. Design

- needs to be structurally designed
- infiltration rate designed in order of magnitude more than rainfall intensity
- temporary subsurface storage provided
- geofabric can be used as filtration treatment near the surface
- sediments and debris must be prevented from contaminating the pavement

Figure 9-34 - Key design criteria for permeable surfaces

9.8.3.1. Design considerations

There are a variety of permeable surfacing materials available ranging from sets to flags. Each will permit different joint widths and thus infiltration rates.

The key design element for permeable paving is the sizing of sub-base materials to provide both water storage and structural capacity. Permeable pavements need to be designed structurally to meet loading and traffic requirements based on the strength of the underlying ground when it is wet. However, the calculations are simple and there is a British Standard for guidance. Thus the design and specification for permeable paving is important:

- Typically you will need blocks to be sat on approximately 50mm of laying course. This should be 2mm to 6mm grit, not sand, to allow percolation.
- The jointing material should be grit too.
- The next layer is a permeable sub-base whose depth is determined by the design. This should be 4mm to 20mm stone and could be between 150mm and 300mm thick.
- A perforated drainage pipe sites in the base of that sub-base layer. An alternative to a pipe would be to use a fin drain alongside the kerbing to provide a formal drainage route along the paving.

- The sub-base is separated from the subgrade by a separation geofabric. Where contamination is an issue, this could be replaced with an impermeable liner to prevent contamination of the ground.

Figure 9 35 – Example permeable paving with piped outlet (Interpave)

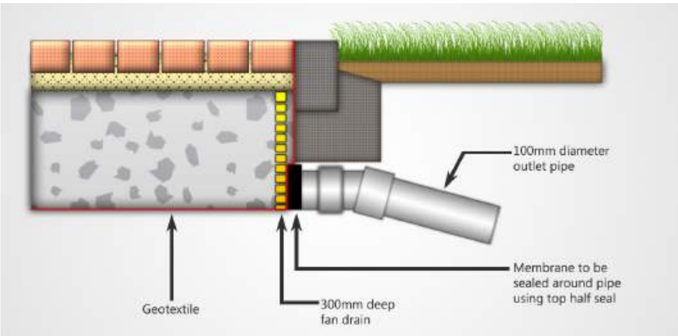


Figure 9-36 - Buried drainage layer

Overflows can be incorporated into the pavement design to drain the sub-base and move excess water onwards through the SuDS treatment train. This will also ensure surfaces are kept free of water at all times. The need for an outlet from the permeable pavement will depend on the permeability of the subgrade. Where this is required, a high permeability buried drainage layer can be incorporated – subject to design and loading conditions. Such a material is shown in Figure 10-37. The need for a piped outlet from the permeable pavement again depends on the overall design - Table 10.15 provides some guidance.

Table 9.15 – Need for outlets on permeable paving

	Total infiltration – no outlet needed	Partial infiltration – outlet needed	No infiltration – outlet needed
High Subgrade permeability (k) 10^{-6} – 10^{-3} m/s	✓	✓	✓
Subgrade permeability (k) 10^{-8} – 10^{-6} m/s	✗	✓	✓
Low Subgrade permeability(k) 10^{-10} – 10^{-8} m/s	✗	✗	✓
Groundwater within 1m of formation?	✗	✗	✓
Pollutants present	✗	✗	✓

You should consider permeable paving as the default option for all hard-standing areas – such as car parks, driveways and access roads, and design them for the 1 in 100 year rainfall event.

Permeable paving can be susceptible to sediment being washed into it from the surrounding areas and blinding the joints in the blocks that allow the water to reach the sub surface. The placement of surrounding features such as grass areas should be considered when placing permeable paving to manage this risk. Because of this risk, American and German experiences suggest that the pavements should be designed assuming an infiltration rate of only 10% of that achievable.

However, even after allowing for clogging, studies have shown that the long-term infiltration capability of permeable pavements will normally substantially exceed UK hydrological requirements. The typical rainfall rate in the UK is 35mm/hour to 80mm/hour: the percolation rate through joints of newly laid CBPP can be 4000mm/hour, so even allowing for the reduction to just 10%, there is a large factor of safety.

It should be noted that CIRIA guidance allows for infiltration in the base of the permeable pavement, yet the BRE365 approach does not as it assumed the base is blinded as in a traditional soakaway system.

In general, some of the main design aspects to consider include:

- Permeable paved areas need to be structurally designed to meet appropriate usage requirements (e.g. is the area purely pedestrian usage or trafficked?) and consider the contributing areas for rainfall. All structural highway design must be verified by a qualified engineer.
- Sub surface storage (where used) should be appropriate for required design events and you should consider the impact of sloping areas. Baffles could be used within the perforated pipe, or sub-base to enhance any storage. The structural stability (loading and stability of the sub soil) should be taken into account as well. Different usage requires different designs.
- The interception storage will vary with the porosity and void ratio of the sub-base used. This might be typically 30% for single sized gravels and 80%-95% for plastic geocellular boxes.
- Permeable paving will not be suitable where the groundwater table is typically within 1m of the base of the sub surface storage – as this will prevent sufficient infiltration to the ground.
- Geotextile material may be used as a treatment layer to trap pollutants depending on area usage and design considerations.
- Surrounding details (such as grassed areas) should be designed to prevent sediments reaching the permeable surface – this might include using filter strips or filter drainage along the edging of the permeable pavement.
- Consideration should be made for service corridors and how the permeable pavement will pass over it – this may be only as far as laying patterns – but needs considering.

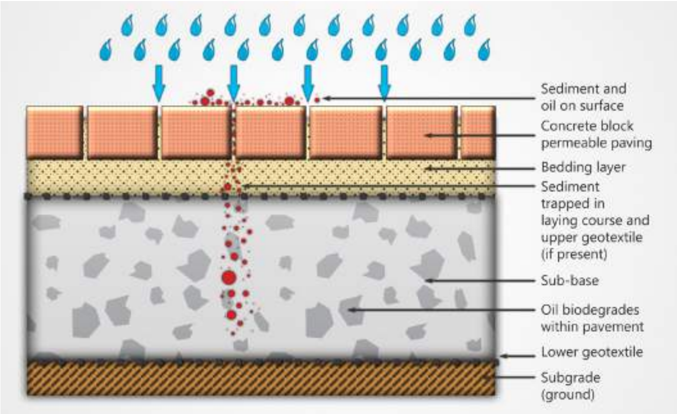


Figure 9-37 - Typical permeable pavement (Interpave)

9.8.3.2. Filter drain Dos and Don'ts

A summary of the Dos and don'ts for filter drain installation can be seen in the table below:

Table 9-16 – Filter Drain Dos and Don'ts

Do	Don't
Install feature last on site to protect from construction site use	Allow paving to collect run-off from unwanted external sources
Use a precautionary design infiltration rate to account for future clogging of the joints.	Have a surface gradient steeper than 1/40 which will cause the water to pond at the low spots
Take into consideration additional guidance: Interpave Understand Permeable Paving	Infiltrate where foundations could be effected, unless protection measures are in place
Take both structural and hydraulic requirements of the pavement into account	Drain excessive surface water flows overland to the permeable surface so that the permeable surface is inundated with flows (where water is unable to percolate through the surface to the sub-base below quickly enough)
Assess the use of pavement when selecting the type of surface material	Incorporate gully pots in permeable paved areas unless absolutely necessary
Consider silt traps or sediment control device at each inlet and outlet point of SuDS	Underestimate skidding and turning effect of the vehicles on the pavement surface. In general, permeable paving is not appropriate in turning areas as the blocks get displaced by tyres. Stone mastic asphalt might be a better alternative in these areas.

Perhaps the best source of information on permeable paving is the Interpave manual. You should seek guidance from their guide: Understanding Permeable Paving, or their website http://paving.org.uk. Additional guidance can be found in CIRIA C582.

Figure 9-38 – Permeable paving in schools and commercial developments (Interpave)

9.8.4. Construction

The construction phase for permeable paving is critical. Care must be taken to ensure that the right founding layers are placed and compacted correctly. The blocks must be laid in accordance with the manufacturer's specifications, and only grit used for the jointing material.

Preventing sediment from entering the base and surface during construction is vital to ensure that the pavement remains permeable throughout its design life.

9.8.5. Maintenance

Permeable pavements have proven themselves over decades of successful use around the world. The performance of the block paved surface is well understood. The infiltration rate of permeable paving will decrease due to the build-up of detritus in the jointing material, then stabilise with age.

Experience thus recommends that the design infiltration rate through the surface should be 10% of the initial rate, to take into account the effect of clogging over a 20-year design life without maintenance.

Maintenance is minimal – no more extensive than that for paving and much less than for traditional gully and pipe drainage. Examples across the UK demonstrate the continuing performance of permeable paving with no maintenance over 5 years.

Some manufacturers do recommend sweeping twice a year as a precaution against clogging. If the pavement does clog completely it may be possible to rehabilitate it using a road sweeper.

Water ponding on the surface will almost certainly indicate that there is insufficient infiltration and the joints/voids may require sweeping clean or, in extreme cases, replacing.

As with conventional block pavements, depressions, rutting and cracked or broken blocks, are considered to be detrimental to the performance of the pavement and will require appropriate corrective action.

Gloucestershire County Council prefers the use of permeable surfacing within adopted highways, or within areas that will be maintained by a management company.

The table overleaf summarised the types of maintenance and indicates their likely frequency:

Table 9-17 – Permeable Surfacing Maintenance and Frequency

Maintenance Frequency	Actions Required	Maintenance Frequency	Maintenance effort
Regular (e.g. Monthly)	Litter removal. Also removal of debris from site.	Monthly	1 site visit with 3 men assuming 1 light van,
	Inspect for evidence of poor operation and/or weed growth. If required, take remedial action.	Three times per year, preferably 48 hrs after large storms.	Included in above site visit
	Stabilise and mow adjacent soft landscaping areas.	Three times per year	Included in above site visit. Mower and ancillary equipment.
	Inspect silt accumulation rates and establish appropriate brushing frequencies	Annually	Included in above site visit
	Surface brushing to remove silt accretion and for aesthetics.	As required	Included in above site visit
	Removal of weeds from gaps in surfacing. Cutting of grass and removal of other ground level overhanging vegetation	Three times per year	Included in above site visit
	Check condition of connected control structures and outlets, rodding eyes and flow control (if present) for debris and silt.	Monthly	Included in above site visit
Occasional Tasks	Brushing and suction sweeping or alternatively jet washing and suction sweeping to remove silt and debris. This is particularly important during autumn with falling leaves. Replacing of lost grit/material may be required	As required – possibly annually	1 site visit with 3 men assuming 1 light van and appropriate equipment. Once per year
Remedial/Repair (when needed)	Resetting of uneven blocks by lifting block area, removing bedding materials and relaying to match original design.	As required (if infiltration performance is reduced as a result of significant blocking)	-

Other product specific maintenance requirements can be found from the manufacturer. A suitable maintenance regime must be followed to ensure the continued performance of the permeable surface.

9.9. Channel systems

9.9.1. What are channel systems?

Channel systems are linear open water features which include options such as canals, rills and other engineered sections with defined edges which convey surface water from one place to another. They can be designed in a variety of styles and, due to the fact that they are "engineered" structures, they can be designed to suit the site specific requirements for a given development. Canals are larger versions of rills, which are typically found in landscaped open space.

Channel systems have a small space requirement in comparison with some other SuDS options and as such may be considered on developments where space is at a premium. They are however, typically engineered and thus less organic and natural than other alternatives such as swales.

Figure 9-39 – Typical rill channel (Susdrain)

9.9.2. How do they work?

Channel systems can be used to capture surface water flows straight from permeable, or impermeable, surfaces without the need for additional silt trapping as any flows entering the channel can be slowed, allowing silty material to settle. For this reason it may be suitable to use a channel system as a pre-treatment option for another SuDS feature.

Once within a channel, the feature can hold surface water at a location allowing water to evaporate, be treated by the sunlight, or be aerated. The channel can convey water on to the next element of the SuDS system through an appropriately designed outlet structure.

In addition to simply capturing and moving surface water run-off, it is possible to incorporate vegetation/planting within the channel that can help to treat the water entering the channel. Much in the same way as other SuDS, the vegetation can help to capture and break-down pollutants entering the channel (e.g. fuels washed off from adjoining carriageways).

Figure 9-40 – Typical rill channel (Susdrain)

9.9.3. Design

the channels create a pre-treatment sump to capture suspended solids

use a maximum water depth of 300mm

limit flow velocity to a maximum of 1m/s

Figure 9-41 - Key design criteria for channel systems

9.9.3.1. Design considerations

Due to the engineered nature of channel systems, designs are not as space constrained as those of other SuDS systems. Channel systems can be flexibly integrated into sites with limited or unusual space to provide a SuDS feature where another option would not fit or be suitable.

Figure 9-42 – Typical rill channel linked to downpipes

The visual impact of the channel system can be reduced through the incorporation of appropriate vegetation which can improve the SuDS aesthetically whilst also improving the performance of the channel.

Rills and canals differ from the traditional linear drainage and slot drains by having readily open and accessible channels -as opposed to being covered with gratings. In general, some of the main design aspects to consider include:

1. Design will differ depending on the primary purpose of the channel (e.g. evaporation or flow transfer)
2. How will the channel system be incorporated into the wider SuDS system? Appropriate inlet and outlet flow control structures should be included in the design
3. All channel drainage assets must have suitable vehicular crossing points, in the appropriate locations and number.
4. Despite being a hard SuDS solution, channel drains should be landscaped so that they appear natural in the context of the surroundings.
5. Channel drains are to be sized to carry 1 in 30 and 1 in 100 year flows, inclusive of an allowance for climate change, generated by the catchment. The sizing of the channel will need to account for the contributing area.

For further channel details and appropriate design guidance refer to CIRIA C698 – Site handbook for the construction of SuDS.

9.9.3.2. Channel drain Dos and Don’ts

A summary of the Dos and don’ts for channel drain installation can be seen in the table below:

Table 9-18 – Do’s and Don’ts for channel drainage

Do	Don’t
Use where space is constrained and consider incorporating the channels in an innovative way	Install until the risk of damage by ongoing site works is minimal
Install as part of initial site works to aid onsite drainage but protect from damage/siltation during construction activities	Install vegetation until later stages of works to minimise risk of damage
Install in-channel vegetation during the final stages of landscaping to avoid damage	Install in areas where “soft” engineering solutions are stipulated
Consider sediment/silt traps at each inlet or outlet point	Use where likely to cause trip hazards
Use appropriate planting to minimise visual impact of “hard” engineering and consider planting depending on location of the channel	

9.9.4. Construction

The construction phase of conveyance channels needs to be considered around the wider site construction. Specific crossing places may be required for plant and materials.

Care should be taken to ensure that all surfaces falling to the linear channels are constructed and finished well, avoiding any trip hazards through settlement or poor levelling.

Sediment should be prevented from entering the channel during construction and the channels should be cleaned on completing the site works.

9.9.5. Maintenance

The maintenance of channel systems can be simple when well designed. Routine maintenance will include removal of debris, whilst more thorough cleaning can be done every few years.

Figure 9-43 – Typical SuDS channel

Figure 9-44 – Overgrown channel outfall

Table 9-19 – Channel systems – maintenance

Maintenance Frequency	Actions Required	Maintenance Frequency	Maintenance Effort
Regular maintenance	Litter removal. Also removal of debris from site.	Monthly	1 site visit with 3 men assuming 1 light van, mower and ancillary equipment
Occasional maintenance	Removal of leaves during autumn to prevent blockage of the channel.	As required	Included within above site visit
	Inspection and clearance of control structures	Annual	Included within above site visit
	Inspection and clearance of control structures	Every 2 or 3 years.	Included within above site visit

It should be noted that, if designed correctly, the maintenance of channel systems can be minimal.

9.10. Geocellular systems

9.10.1. What are Geocellular systems?

Modular plastic 'geocellular' box storage systems, with a high void ratio, are below ground storage arrangement that can replace underground pipes or concrete tanks used in the past to store water. They can also be used to convey or infiltrate runoff into the ground. It is important to recognise that all below ground storage structures only provide attenuation (storage) of runoff and not treatment.

Cleaning of runoff is required before storage or release to the environment.
Underground storage features attenuate an agreed volume with a control structure to limit the discharge to an agreed flow rate.

Silt interception and a clear management arrangement is critical to long term effectiveness of these structures and this must be demonstrated at design stage and confirmed for the design life of the development.

9.10.2. How do they work?

There are two basic modular box arrangements.

1. A modular box system with inlet and outlet pipe work connected to the sides of the structure.
2. A honeycomb structure with perforated pipes running under or through the box. Water is forced into the box when flows increase.

Recently shallow, load bearing boxes have been developed that can be used as sub-base replacement. In particular they can be used below permeable pavement which protects the box from silt contamination, and provides treatment before water enters the box for storage. The structural design of any underground storage structure must be verified by a qualified Structural Engineer.

Figure 9-45 – Geocellular boxes used as sub-base for permeable pavement

Geocellular boxes can have advantages over conventional in-situ tanks or concrete pipes as they are spatially versatile and are easy to install. They can also allow infiltration through a geotextile liner in suitable soils.

9.10.3. Design

To carry out water quality treatment, these systems need to be part of a SuDS management train, with appropriate sediment management and pollution control devices installed within or before the installation.

The preferred method of runoff collection is through permeable pavement because silt is trapped on the surface and runoff passes through crushed stone and geotextile to provide cleaning before below ground storage.

The hydraulic design of on or off-line storage using pipes or tanks should be in accordance with Sewers for Adoption, 6th Edition (WRC 2006).

Infiltration systems should be designed to comply with current guidelines (BRE 365 1991 or CIRIA publication R156 Bettess 1996) and storage systems should be designed using standard routing methods set out in Chapter 4 of The SuDS Manual 2007.

The structural design of tanks and pipes should be in accordance with relevant standards e.g. Sewers for Adoption, 6th Edition (WRC 2006) and BSEN 1295 (BSI 1998).

Structural design for buried pipelines under various conditions of loading, Highways Agency specification for highway works (Highways Agency et al, 1998).
Design of geocellular structures should be in accordance with 'Structural design of modular geocellular drainage tanks' CIRIA Report C680.

9.10.4. Maintenance

As desilting of the boxes could be difficult during operation, special care needs to be put in designing and maintaining the inlet structures to enable silt accumulation before flow enters the boxes. Regular maintenance of these structures is required to enable their adequate function.

Table 9-20 – Geocellular boxes – maintenance

Maintenance Frequency	Actions Required	Maintenance Frequency
Regular maintenance	Inspect and remove debris from inlet structure	Monthly
	Remove sediment from pre-treatment structure where present	Monthly or as required
	Check inlets, outlets, control structure and overflows	Annually or as required
Occasional maintenance	Jetting and suction where silt has settled in the structure	As required
Remedial work	Full replacement of the structure if permanently silted or structural failure	As required

10 Inlets, outlets and flow control structures

10 Inlets, outlets and flow control structures

10.1. What are inlets, outlets and flow controls?

Inlets, outlets and flow controls are the key aspects of SuDS that manage the water into and out of each part of the system and regulate the flow to the required design rate. They are the primary links between SuDS components and the key aspect of ensuring flow and volumetric control.

- Inlets- convey water into a system or section of the SuDS train
- Outlets- convey water out of system or section of the SuDS train
- Controls- restrict flow rates, volumes and velocities

Figure 10-1 – SuDS pond with inlets and outlet

10.2. How do they work?

The principles of SuDS design are to reduce the flow rate, improve water quality and provide amenity features as surface water runoff is conveyed through the system. In order to achieve this SuDS are divided into small collection areas and use control structures to limit flow quantity, rate and velocity.

Control structures are flow restriction devices that limit the rate at which water can leave a SuDS feature. As it rains, the water backs up and fills the storage area (pond, basin, swale, etc.). For example, where a site discharge is restricted to 6l/s with a peak runoff of 10l/s, the excess water needs to be stored by applying a control that limits the flow leaving the site.

The extent of control provided is governed by its hydraulic performance. The control is typically located at the inlets and outlets of the SuDS components.
As velocities are kept low in SuDS networks, the need for erosion control features and large concrete structures, such as vertical headwalls at the inlets and outlets, is often reduced compared to traditional drainage systems.

10.3. Design

- provide an overflow outlet
- provide exceedance flow paths around the feature
- use surface flow controls where possible
- protect all pipes flow controls where possible
- protect all pipe inlets and outlets from blockage and unauthorised access
- be kept to a mimimum
- be inconspicuous

10-2 - Summary of considerations for criteria for inlets, outlets and controls

10.3.1. Design considerations

As well as being hydraulically designed to regulate flows, inlet and outlet structures should also incorporate safe access for maintenance using typical amenity mowing equipment.

Both inlets and outlets can act as controls, being typically weirs or orifices. Note that the standard design equations assume a free discharge so the downstream situation must be considered. This might mean the need to test drowned or submerged conditions on the hydraulics, or additional allowances for overflow.

The design of the inlet, outlet and control must consider the following:

- geotechnical constraints including erosion and sedimentation risk;
- structural design;
- hydraulic performance including the impact on water quantity;
- safety for maintenance and safety of the public and wildlife;
- amenity value - wherever possible, SuDS structures should also add interest to the urban landscape and not detract from the overall aesthetic; interest can be added to the associated landscaping by thoughtful design of the control structures.

The low velocities associated with SuDS allow the settlement of the sediments. Silt traps at the inlet (to prevent transport of sediment into SuDS and allow easier maintenance) and at the outlet (to prevent wash-off of pollutants from SuDS entering the watercourse during exceedance storms) should form part of the overall SuDS treatment train.

The use of standard gully pots will add to the maintenance costs of the SuDS and pose hazards to wildlife and can be fatal for newts and other small creatures. The phenomena, known as the 'gully pot issue', can be obviated by inclusion of wildlife ramps in sump features, to allow wildlife to crawl out. These can be seen in most new cattle grid installations.

Figure 10-3 – Inlet and outlet using a stone basket

If traditional drainage systems are proposed as part of the overall site drainage strategy, they all must be designed in accordance with the current Sewers for Adoption[13] guide or Design manual for Roads and Bridges[14] (DRMB).

A self-cleansing velocity of 1m/s is required for all pipework and adequate pipe sizes should be used to maintain it.

Design of road gullies must follow the Gloucestershire County Council specifications. Road gully spacing must not be greater than 40m, irrespective of the area drained. All gullies should be trapped and the maximum length of a gully connection must not exceed 15m. Each gully must have its own connection into the surface water drain.

The design of gullies and the sewer they discharge into must ensure no flooding for a one in 30 year storm. It should be noted that the DMRB states, "Highway drainage systems are designed to intercept and remove rainfall from short duration, high intensity events with return periods of 1 year (for no surcharge of piped systems or road-edge channels) or 5 years for no flooding of the carriageway."

[13] Water UK / WRc (August 2012) Sewers for Adoption, 7th edition

[14] Highways Agency (January 2014) Design manual for roads and bridges incorporating amendments dated February 2013, published by The Stationery Office.

Gullies will be required immediately upstream of pedestrian crossing points and road junctions. However, Gullies must not be positioned on pedestrian or vehicular crossing points.

At all low points where blockage of the gully outlet could result in damage to property, and for highway safety and highway maintenance reasons, two separately connected gullies will be required into the main drain run.

The second gully shall be slightly removed (positioned at a slightly higher elevation in the road) from the low point such that any run-off resulting from a blockage of the gully at the low point may be readily detected and will drain into the second without causing any risk of flooding to nearby properties.

Any existing gully which lies in the bell mouth area of a proposed road must be repositioned, normally on the upstream side of the bell mouth.

Where the longitudinal gradient of the road is less than 1:125 for flexible surfaces and 1:80 for block paved surfaces, a kerb drainage system will be required.

Extra costs will be requested to cover the additional maintenance involved in adopting kerb drainage systems; this cost will be evaluated on a site by site basis.

Petrol interceptors must be installed, where required, as per the manufacturer's guidelines.

The external flows that might discharge into the system must be taken into account. For example the design should consider gutter and gully capacity and the requirement for additional interception features to convey these flows. Without such precautions run-off from garden areas, for example, could overload a drainage system that was designed only for the roofs and roads.

10.3.2. Hydraulics

The hydraulic design calculations submitted with your SuDS proposal must determine the required attenuated volume and peak flow control.

A minimum discharge rate is 5l/s is recommended by CIRIA when applying flow controls.

The principle applied in the design of storage is to restrict the discharge from the site for events of same frequency of occurrence to the same peak rate of runoff as that which took place from the site prior to development (See Chapter 5.2). Using minimum pipe sizes and other controls, it is not practical to control the discharge rate to below 5 l/s.

This is also partly in order to minimise the risk of outlet blockage. Peak flows less than this are more likely to give rise to deposition and then blockage.

Figure 10-4 – SuDS pond with orifice inlet and notch weir outlet

For greenfield sites, the proposed drainage system must ensure:

- the discharge flow rate for a 1 in 1 year rainfall event is limited to the 1 year greenfield run-off-rate, or 5l/s, whichever is the greater;
- the discharge flow rate for a 1 in 100 year rainfall event is limited to the 100 year greenfield run-off-rate;
- controlled overland flooding for a 100 year event with a 20% allowance for climate change;
- the total amount of drainage water leaving the development site during a 1 in 100 year storm of 6 hours duration must not exceed that from the same event for the greenfield site;
- where these requirements cannot be met, the additional volume may be released at a rate that does not adversely affect the off-site flood risk, and must be agreed with Gloucestershire County Council. This long term storage requirement will be based on the National Standards of 2l/s per hectare or 5l/s, whichever is greater.

A kerbed road surface may provide an important contribution to flood risk management by providing a drainage path for overland flood flow should the storm return period exceed 30 years. However the drainage design must ensure there are no detrimental impacts to people or property during the 100 year event with allowance for climate change.

Vortex flow controls maximise the use of the available attenuation volume and permit a more or less constant discharge rate even at low flow, assuming a free discharge downstream. A similar performance can be achieved by designing a multilevel orifice control, perhaps having decreasing orifice sizes with depth of flow. This also provides a degree of resilience should one orifice block.

10.3.3. Exceedance

The design of any inlet, outlet or control must consider the impact of exceedance events that could quickly overwhelm the SuDS components. The design must include an overland flow route so that the excess surface water can be managed.

Slight depressions in the local topography can be utilised as sacrificial flow routes such that excess water can flow around the inundated SuDS feature. The site layout should identify the overland flow routes during exceedance rainfall events and these should not adversely impact on the infrastructure or the safety of its users.

10.3.4. Blockage

The design of weirs and orifices should accommodate shallow flowing water and varying heads. They need to be protected from blockage by, for example grass clippings or general litter, an inherent risk in any surface system.

Figure 10-5 – SuDS outlet with trash screen

Blockage will render the storage facility ineffective, as the feature will fill un-necessarily, taking up vital storage volume and discharging less than the permitted flow.

The installation of grilles and screens does not necessarily accord with the SuDS design principle, being both potential blockage and trip hazards.

Partially covered mesh, or loose rock in fills to inlets and outlets, can offer a screen against blockage and vandalism. Similarly, controls housed inside shallow chambers permit easier access and protection from debris or unwarranted attention. However, care must be taken to ensure that any screening does not, in itself, increase the risk of blockage and failure of the asset.

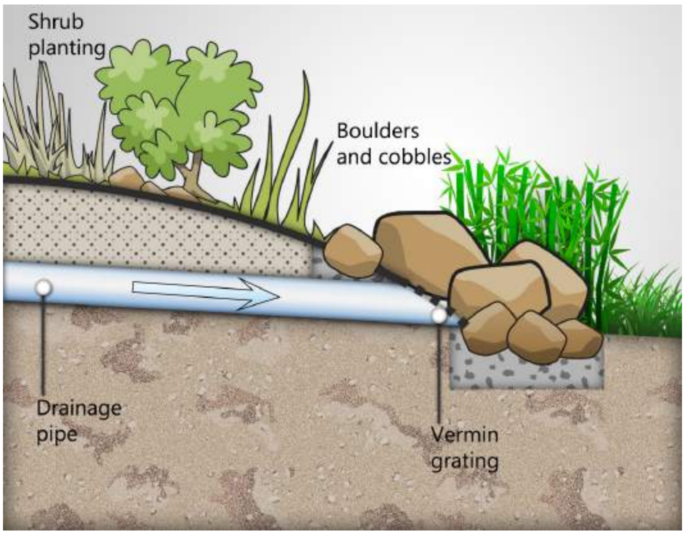


Figure 10-6 – Example buried inlet (Susdrain)

10.3.5. Example inlets, outlets and controls

Refer to CIRIA SuDS Manual (C697) for a more complete range of inlet, outlet and flow control options and design guidance. As a rule, all inlets, outlets and controls should be placed as near as possible to surrounding ground surface (shallow) – making them easier to inspect and maintain.

Below are some examples of inlet and outlets control structures.

Figure 10-7 – Kerb inlets

Example of inlets:

- pipe inlets with a mitred collar headwall;
- combined inlet and planting pit systems;
- combined kerb and drainage systems;
- permeable surfacing with infiltration or underdrains;
- flow splitters which divert the initial flush to interception storage, while allowing the flow of larger storms to bypass.

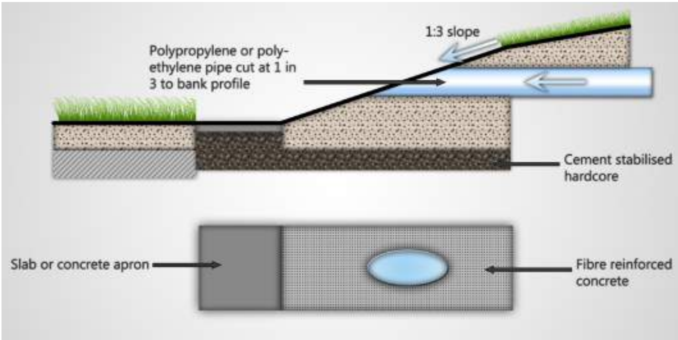


Figure 10-8 – Pipe inlet with concrete collar

Example of outlets:

- flow restriction devices such as orifice plates or vortex control devices located within manholes or other chambers;
- Simple pipe outlets with a mitred collar, which restrict flow rates;
- chambered risers and orifices;
- underdrains which collect water that has filtered through a porous medium and convey it to the next SuDS feature;
- permeable weirs allow water to flow slowly through smaller openings (e.g. stone gabions);
- overflows to manage exceedance events or blockages;
- gaps in walls or kerbing – slot weirs;
- overflow weirs; and
- level spreaders which disperse a concentrated flow and release it at lower velocity.

Figure 10-9 – Slot weirs

Most of the time surface water runoff is transferred to the next part of the management train but sometimes overflows may flow directly to an exceedance flow route. In open structures the overflow will often take the form of a dished weir or spillway.

10.3.6. Inlets, outlets and controls - Dos and Don'ts

The following table summarises the key issues for inclusion of ponds in your SuDS scheme.

Table 10-1 – Summary of considerations for inlets, outlets and controls

Do	Don't
Consider hydraulic performance in line with overall volume and flow rate requirements	Include concrete headwalls, gullies and deep chambers
Ensure safe access for maintenance	Forget to demonstrate the design for each control, and its maintenance needs, in your various submissions
Make head walls inconspicuous and kept to a minimum	Increase the chance of blockage by allowing sediments and debris to collect on them
Make allowance for blockage and exceedance flows by including other flow routes	

Every effort should be made to integrate the inlets and outlets with the surrounding landscape. As shown in the figure below, poor headwall design can create an eyesore in the environment.

Figure 10-10 – Poor headwall design

10.4. Construction

The construction of the inlets, outlets and controls will be critical to the SuDS installation.

The attenuating and flow control performance of the control will depend upon fine tolerances in the construction, and should be specified in the design. For example, an invert level on a 300mm diameter outlet 10mm in error can make 2l/s difference to the outflow.

Given that each feature will include man-made materials (pipework, concrete, blockwork etc.), the construction should ensure that all landscaped areas and components are adequately finished and made good.

10.5. Maintenance

To afford maintenance, each feature must be provided with suitable access – albeit shallow slopes or steps. Consideration must be made of how the feature will be maintained, such as where the operative might stand and where and debris removed can be temporarily stored. There will be a trade-off between accessibility and security.

As described above, all inlets, outlets and controls should be located as near as possible to ground surface to permit ease of maintenance. Such maintenance will include the removal of debris, but where the feature is buried or enclosed, additional maintenance liability will be created.

Clearance of debris should ensure that materials are removed from the immediate site and not allowed to fall back into the inlet, outlet or control.

Figure 10-11 – Pipe inlet in need of maintenance

The table blow summarised the types of maintenance and indicates their likely frequency:

Table 10-2 – Inlets, outlets and controls – maintenance

Maintenance Frequency	Required Action	Maintenance Frequency	Maintenance effort
Regular Maintenance	Inspect inlets, outlets and overflows for blockages, and clear if required	Monthly during first year – then every 3 months	Assume 1 site visit with 3 men assuming 1 light van, mower and ancillary equipment
Occasional Maintenance	Inspect inlets, outlets and overflows for sediment and blockages, and clear if required	3 times a year	Included within above site visit
Reactive Actions	Replace controls if damaged or modify when shown to be performing incorrectly	As required	2 site visits with 3 men, 1 light van, small plant and ancillary equipment.

11 Health & safety

11 | Health & safety

11.1. Health & Safety

A Health and Safety review of SuDS features involves both a consideration of public acceptance as well as a practical assessment of risk and consequence. Society generally accepts the benefits and desirability of clean, attractive and safe water features in public open spaces. That said the primary risk for SuDS features is the risk of drowning.

All structures associated with SuDS in Gloucestershire should be evaluated for risk to the public, maintenance staff and wildlife.

The SuDS designer must demonstrate measures taken to reduce the possibility of harm to the public, or maintenance staff, which should be agreed with Gloucestershire County Council during the design approval process.

11.2. Design

Under the CDM Regulations 2015, the SuDS designer has a responsibility to eliminate hazards by designing them out if possible. Health and Safety issues should be considered throughout the design process with the aim of delivering SuDS that are safe and easy to maintain.

All open water features should be carefully assessed, particularly regarding access by young children. According to ROSPA data, the greatest risk is to young men between the ages of 16 and 34, and caused by swimming in open water. Shallow water will minimise this risk of drowning and the chance of getting stuck face down in shallow water is generally unlikely after the age of 5.

As designers, you must take all reasonable measures to minimise the risk of drowning or harm in any other way and consider your liabilities.

The common quoted concerns are of water safety and drowning; of an accumulation of toxic material (sediment in swales); of vehicles driving into and overturning in swales.

Vandalism, misuse and durability of the features should also be taken into account when designing SuDS.

Design risk mitigation measures

The following provides a list of potential risk mitigation measures to be considered during the design process:

- avoid high vertical drops/headwalls;
- slopes no greater than 1 in 3 to allow people and maintenance machinery to enter and leave the SuDS features safely;
- avoid fast flowing water (prefer maximum velocities of 0.5m/s) and avoid areas that become inundated very quickly;
- fencing must be considered carefully and proportionate to the site risk level. Unrestricted visibility is required to all accessible water features;
- marginal planting can create physical protection but should not obstruct visibility of the water from the surrounding area;
- safety grills should be placed on pipes greater than 350mm or greater diameter, with slopes at an angle of 45 degree so that debris is likely to lodge against them yet not block;
- a maximum storage depth of 450mm to 600mm is acceptable for swales;
- pollution and nutrients should be removed at source by designing the SuDS in accordance with the SuDS management train to avoid contamination and disease;
- where a person could fall more than 2m, a fence should be considered (although this situation should be designed out wherever possible);
- a level dry bench at the top of all open structures, 1m minimum wide, allows stationary rest for a person and safe access – i.e. make it easy to exit;
- a wet bench, 1m minimum wide to all water features allows stationary rest for a person and safe access;
- gullies, silt trap pits, catchpits and other sumps should be avoided wherever possible to reduce risk to wildlife and pedestrians and
- danger signs and life-saving equipment for SuDS features should not be necessary where the conditions set out above are followed as SuDS should be considered inherently safe features in the landscape.

11.3. Maintenance

Consideration of the CDM regulations must be made for the long term maintenance of SuDS. In Gloucestershire, we would expect:

- all SuDS features to afford safe and secure access for maintenance;

- any drainage asset that requires maintenance must have suitable vehicular access;
- access points for vehicles should be level, secure and stable;
- access must be available to all parts of a SuDS feature and at least from one side for machine work;
- any above ground SuDS feature shall be designed with slopes not exceeding 1 in 3 to allow for maintenance, access and egress; and
- other than for ponds, the maximum depth of standing water should be no more than 600mm.
- An appropriate maintenance strategy should be in place. This should account for regular litter bins to minimise the need for operatives to enter the SuDS feature, and routine site litter picks as well as regular landscaping maintenance.
- In addition, maintenance staff should be educated to observe safe systems of work in order to mitigate any remaining risk associated with untreated / polluted water.

11.4. Operation

- It has been demonstrated that public education and good design are crucial in managing and addressing perceived risks.
- Where thought necessary, danger signs can be displayed next to the hazard in order to raise risk awareness and educate users about Health and Safety risks but care should be taken not to unduly scare users of the site.
- Owner / occupiers should be informed about the function of their local SuDS and the level of risk posed by the feature.
- Training in local schools could be considered to raise risk awareness for children.

11.4.1. Drowning risk

- Fear of drowning is a reasonable anxiety in the users of sites with surface water bodies, particularly in residential areas. Young children below the age of 5 may not understand the danger of open water so need special consideration.
- However, users become more comfortable with water so long that entry and exit from the water are straightforward and unhindered, and where the depth of water remains shallow.
- The need for variety within your SuDS installation should be compatible with a safe and easily managed open space. It is a matter of design to ensure that steps, benches and gently sloping banks are included.
- Measures to ensure reasonable safety should be based on guidance, best practice and judgement. For full details and advice on managing risk around waterbodies, consult the ROSPA website at: http://www.rospa.com/leisuresafety/adviceandinformation/watersafety/pond-garden-watersafety.aspx

11.4.2. Trips, slips and falls

- Any surface structure will present a hazard to people. There are a number of specific SuDS features that require safety to be considered in their design: inlets and outlets, control structures, inspection chambers, weirs and others.
- Gully pots, pipes, chambers, and other sumps in the landscape can be a hazard to wildlife as well as people, and should be ‘designed-out’ where possible.

11.4.3. Dirty water

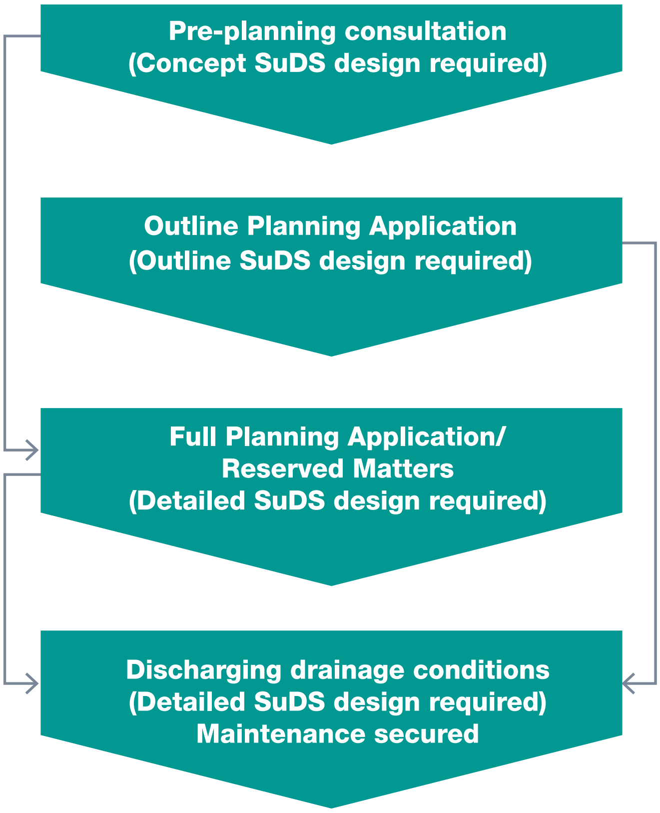
- One of the aims of SuDS is to remove pollutants from surface water.
- The risk of mis-connections of waste water, common in traditional piped drainage systems, is removed by using SuDS. Rainwater runoff that has passed through a SuDS system results in clean, low nutrient water that is good for wildlife and which poses minimum risk for people.
- SuDS management trains that feature multiple treatment stages maximise the quality of surface water for wildlife and people.

12 SuDS Approval & maintenance

12 SuDS Approval & maintenance

12.1. SuDS Approval & maintenance

Approval of SuDS will be undertaken through the regular planning process. The design approval of SuDS comprises of three stages and follows the regular planning approval stages:



Confirmation of critical features at each design stage is required to ensure approval of a SuDS scheme.

12.2. Conceptual Drainage Design

This preliminary design stage provides an opportunity for the developer to indicate the nature of the proposals and discharge location for development runoff. The checklist of data required is provided in Appendix B.3 and the Outline Planning Application Process in Appendix C.1.

12.3. Outline Drainage Design

A preliminary SuDS design statement to explain the proposal is required which should include preliminary calculations to quantify pre- and post-development run-off rates and volumes. The proposal should describe ideas for integrating the drainage system into the landscape or required public open space and the methods that will be used for linking systems together and managing flows in excess of the design event. At this stage there should be no need to submit initial calculations, but they should be carried out to roughly size any significant drainage structures. An estimate of any storage required for the development and where it is to be located within the site along with the extent of any other SuDS techniques should be provided on an Outline Drainage Proposals drawing. An agreement in principle from relevant authorities for drainage connections is required at this stage. The checklist of data required is provided in Appendix B.4 and the Full Planning Application Process in Appendix C.2.

12.4. Detailed Drainage Design

Detailed design proposals should be submitted in order to discharge drainage conditions and should include final detailed drawings and appropriate calculations together with copies of all relevant permissions or agreements. These drawings should be approved prior to commencement of the construction. A maintenance plan for SuDS elements should be in place at this stage. Any asset that cannot be maintained will not be approved.

Maintenance must be achievable and consideration of access, removal of waste materials and costs should be made. The checklist of data required is provided in Appendix B.5 and the process for the discharge of drainage design and maintenance conditions in Appendix C.2 and C.3.

12.5. Maintenance Responsibility

For the success of sustainable drainage systems, long-term maintenance arrangements need to be assured; developers will have responsibility for ensuring such arrangements are secured as a requirement of their planning application, whilst the local planning authority should be contacted for pre-application advice on maintenance. Each development could have a number of different options for maintenance arrangement and this should be considered and discussed with the Planning Authority at the pre-planning stage.

For example:

1. Private Management – SuDS located within property boundaries are the responsibility of the property owner and may include green roofs, permeable driveways, water butts, garden soakaways and rain harvesting. Maintenance of this SuDS may be secured through

Section 106 of the Town and Country Planning Act. The Section 106 agreement can cover a whole new housing estate and contain the details of soakaways in individual properties as well as shared SuDS.

2. Commercial/Industrial Sites, Shared Private Space or Roads– SuDS located within development that provide a source or site control function include filter strips, normal and under-drained swales, bio-retention areas and rain-gardens, filter drains, permeable pavement and other local infiltration systems. Underground storage structures such as oversized pipes and geo-cellular boxes are usually located in this area of management. The developer must ensure that a maintenance agreement is in place which could be either through setting up a Management Company, or discussing future maintenance or potential adoption with local Water Company or Local Authority.
3. Public Open Space – SuDS located in open green space, either owned by Local Authorities or with full public access provide conveyance and open storage of clean water that flows from development and include basins, ponds and wetlands linked by swales, linear wetlands and other open channels. Again, the developer must ensure that a maintenance agreement is in place which could be either through setting up a Management Company, or discussing future maintenance or potential adoption with the local Water Company or Local Authority.

Developers are advised to contact the local planning authority for guidance on adoption before submitting a planning application

12.6. Discharging Drainage Conditions

Before approving a SuDS scheme and finally discharging the drainage condition, the Local Planning Authority will request from the developer:

1. A verification report from the developer that the SuDS system has been constructed in accordance with the approved design drawings and in accordance with best practice. If the SuDS system could pose a Health and Safety risk, the verification should also include a Health and Safety audit to check that the local community, visitors and operation and maintenance operatives will not be put at risk. The construction verification and audit could be undertaken by the Local Planning Authority or by an independent body.
2. Evidence that:

- SuDS have been signed off by an appropriate, qualified, indemnified engineer
- the SuDS are explained to prospect owners via Homeowners Pack and information on SuDS entered into the land deeds of the property;
- An agreement that maintenance is in place over the lifetime of the development; and/or
- Evidence that the SuDS will be adopted by a third party.

3. For all site and regional control SuDS, the developer should submit the following documents:

- As built drawings/ Specification sheets for materials used in construction;
- Copy of Final Completion Certificate.

These documents may be entered into the Gloucestershire Council Council's asset database and designated. If designated, any further change of the assets would require consent from the County Council.

This will ensure that all SuDS systems are constructed and maintained to required standard and any changes are registered and agreed with the Lead Local Flood Authority, which takes responsibility for overall local flood risk across Gloucestershire.

A

Appendix A Glossary & abbreviations

A | Appendix A Glossary & abbreviations

A.1. Abbreviations

Act – the Flood and Water Management Act 2010

BAP – Biodiversity Action Plan

CDM – Construction (Design and Management) Regulations 2015

EA – Environment Agency

FRA – flood risk assessment

LLFA – Lead Local Flood Authority

LPA – local planning authority

NPPF – national planning policy framework

RBD – river basin district

Regulations – the sustainable drainage regulations 2012 (draft)

PPE – personal protective equipment

PPS25 – planning policy statement 25 – development and flood risk

SFRA – strategic flood risk assessment

SSSI – site of special scientific interest

SuDS – Sustainable Drainage Systems

A.2. Glossary

Act – The Flood and Water Management Act 2010 from where the Lead Local Flood Authority and need for SuDS adoption arises.

Adoption – Related to someone or an organisation taking responsibility for management and maintenance of the SuDS components.

Amenity – A general term used to describe the tangible and intangible benefits or features associated with a property or location that contribute to its character, comfort, convenience or attractiveness.

Approval – The process of approving all qualifying drainage designs before constructions starts. In order for adoption to take place, certain drainage requirements will need to be met.

Aquatic bench – The level edge in a pond planted with aquatic plants situated just under water level

Aquifer – An underground body of water stored in the natural rock sub-structure.

Attenuation / detention of water – The process of slowing down the rate of flow, reducing the peak, and increasing duration of a flow event.

Basin – A ground depression to hold water and attenuate or provide water treatment that is normally dry and has a proper outfall, but is designed to detain stormwater temporarily.

Biodiversity – The variety of species of plants, animals and ecosystems within a habitat.

Bioretention areas – Planted areas with engineered topsoil over drainage layers that allow water to soak into the ground.

Block paving – Pre-cast concrete or clay brick sized flexible modular paving system.

Brownfield site – A site that has been previously developed.

Construction (Design and Management) Regulations 2007 (CDM) – Construction (Design and Management) Regulations 2007, which emphasise the importance of addressing construction health and safety issues at the design phase of a construction project. These have now been revised by the April 2015 edition.

Catchment – A catchment is an area contributing to a flow at a point in a drainage network or river.

Combined sewer – A combined sewer collects sanitary sewage and stormwater runoff in a single pipe system. Combined sewers can cause serious pollution issues when heavy rain reduces the capacity in the sewers for foul water and overflows pass into the environment. The use of such systems is rarely used in modern drainage design.

Conventional drainage – The traditional method of draining surface water using subsurface pipes and storage tanks

Conveyance – Movement of water from one location to another.

Deposition – Laying down of matter via a natural process.

Detention basins – Detention basins are dry flat areas with shallow depressions used for the temporary storage of excess storm water. In a storm event water accumulates in the depression and then is either slowly discharged to the next SuDS component or to a receiving watercourse.

Ecology – The study of environmental systems, particularly the relations of organisms to one another and to their physical surroundings.

Ecosystem – A biological community of interacting organisms and their physical environment.

Erosion – Natural processes, including weathering, dissolution, abrasion, corrosion, and transportation, by which material is worn away from the earth's surface

Filter drain – Filters drains (also referred to as filter trenches or French drains), are linear excavated trenches which are backfilled with graded rubble or stone and convey water to another feature or allow it to soak into the ground. They are sometimes with a perforated pipe in the bottom. These may be enlarged to treat dirty water, as treatment trenches, or increase soakage into the ground, as infiltration trenches.

Filter strips – Grass verges that allow runoff to flow through vegetation to a swale, wetland, infiltration area or other SuDS technique.

Filtration – Fluid flow through a filter to remove particles and pollutants.

First flush – Initial runoff room a site after a rain event. The first flush often contains the greatest concentration of pollutants.

Floodplain – An adjacent area of land that borders a watercourse, an estuary or the sea, over which water flows in time of flood, or no longer flows due to the presence of flood defences.

Flood routes (exceedance routes) – Allow water volumes exceeding the capacity of the SuDS system to escape from the site without causing damage to property. This route must be clear of obstructions at all times.

Flood storage – The temporary storage of excess runoff or river flow in ponds, basins, reservoirs or on the floodplain during a flood event.

Flow control structures – Usually small orifices in control chamber, slots or vee-notches in weirs. They are usually near the surface so are accessible and easy to maintain.

Forebay – A small basin or pond upstream of the main basin with the specific function of trapping sediment.

Freeboard – The distance between the top of structure and the designed water level, which acts as a safety factor for blockage, failure or calculation uncertainty.

Geocellular – a proprietary system of box shaped cells (normally made from modern plastic materials) used to form an underground void intended to provide attenuation of collected surface water run-off. These can be wrapped in geotextile to provide coarse filtration for pollutants.

Geomembrane – A permeable or impermeable sheet made from modern plastic materials. These are usually placed in the ground as drainage membranes, allowing the passage of water but not fine soil particles. Can also be use as protection from sharp objects for e.g. pond liners.

Geotextile – A plastic fabric usually applied to improve ground strength for bearing.

Greenfield – Land which has not been developed before, other than for agriculture or forestry buildings or buildings associated with parks, recreation grounds and allotments.

Green roof – Green roofs are planted with vegetation cover/landscaping. Green roofs are designed to intercept and retain precipitation, reducing the volume of runoff and attenuating peak flows. Green roofs can also add biodiversity and aesthetic benefit to an area.

Groundwater – Water that is below the surface of the ground in the saturation zone.

Groundwater table – The level at which the water in the ground lies. This is variable with the seasons and annual rainfall.

Gully – An inlet taking runoff from a road into a drainage system, usually through a metal grate and into a sump.

Habitat - The area or environment where an organism or ecological community normally lives or occurs

Impermeable – A surface or material which water cannot penetrate or pass through.

Impervious surface – A surface that does not allow inflow of rainwater into the underlying construction or soil.

Infiltration – The soaking of water into the ground.

Infiltration basins – Trenches, soakaways and most of the preceding SuDS features allow water to soak into the ground.

Infiltration trench – A trench, usually filled with permeable granular material, designed to promote infiltration of surface water to the ground.

Interception storage – The storage of small rainfall events (up to 5mm).

Inlets and outlets – Structures are often conveyance pipes protected with mesh guards. They must be free from obstruction at all times to allow free flow through the SuDS.

Main rivers – Watercourses designated as such on statutory main river maps held by the Environment Agency and Defra. Can include any structure or appliance for controlling or regulating the flow of water in or out of a channel. The Environment Agency has permissive powers to carry out maintenance and improvement works on these rivers.

Maintenance plan – A plan for the SuDS to record information on its functionality and maintenance requirements. This will ensure that the long term performance of the feature meets the needs and expectations.

Non-compliance notice – A non-compliance notice is issued by the authorising authority where aspects of the design or application for approval are incomplete or do not meet the national standards.

Occasional maintenance – Maintenance work that is not considered regular, typically involving rehabilitation and replacement of parts.

Open water – A body of water exposed to the atmosphere – i.e. the water surface is free from emergent and marginal vegetation

Ordinary watercourse – Watercourses designated as such being non main river. Can include any structure or appliance for controlling or regulating the flow of water in or out of a channel. The Lead Local Flood Authority has permissive powers to carry out maintenance and improvement works on these watercourses.

Overflows – Can be below ground through gratings and chambers or over grass weirs in the open They must be kept clear at all times to protect areas from flooding.

Pavement – Any paved surface and underlying structure, usually asphalt, concrete, or block paving. Can be used as road, parking or footway. A permeable surface that is paved and drains through voids between solid parts of the pavement

Peak flow – The maximum flow rate of water in a river during a particular period.

Permeable surface – Can be either porous or permeable. Porous surfacing is a surface that infiltrates water across the entire surface. Permeable surfacing is formed of material that is itself impervious to water but, by virtue of voids formed through the surface, allows infiltration through the pattern of voids.

Pollution – A change in the physical, chemical, radiological or biological quality of a resource (air, water or land) caused by man or man's activities that are injurious to existing, intended or potential use of the resource.

Public open space – The open space required under our planning policies is defined as any land laid out as a public garden or used for the purposes of public recreation. This is space which has unimpeded public access, and which is of a suitable size and nature for sport, active or passive recreation or children and teenagers' play. Private and shared private amenity areas, or private buffer landscape areas are not included as public open space.

Rainfall event – A single occurrence of rainfall before and after which there is a dry period that is sufficient to allow its effect on the drainage system to be defined

Rain gardens – A planted basin designed to collect and clean runoff.

Rainwater harvesting – Collecting and storing rainwater at source rather than allowing runoff. This can include runoff from within the boundaries of a property, roofs and surrounding surfaces.

Reactive maintenance – Maintenance work that is undertaken on an as-required basis to assess unforeseen failure or damage.

Regular maintenance – Maintenance work that is undertaken relatively frequently and with fixed schedules – such as grass cutting

Regulations – The sustainable drainage regulations 2012 (draft)

Retention basins – A retention basin is a SuDS feature akin to a pond. The basin holds water permanently, although may empty during prolonged dry weather. The design of ponds and retention basins are very similar.

Return period – the statistical chance of an event happening expressed in terms of a single change in a given number of years. For example, the 1 in 30 year event is likely to be exceeded at least once every 30 years.

Risk – The chance of an adverse event. The impact of a risk is the combination of the probability of that potential hazard being realised, the severity of the outcome if it is, and the numbers of people exposed to the hazard.

Runoff – The flow of water over the ground surface. This occurs if the ground is impermeable or saturated, if rainfall is particularly intense, or if surface water drainage systems exceed their capacity and overflow.

Sediments – The layer of particles that cover the bottom of water-bodies such as lakes, ponds, rivers and reservoirs. Can include silt, stones etc.

Sewer – A pipe or channel taking domestic foul and/or surface water from buildings and associated paths and hard-standings from two or more cartilages and having a proper outfall.

Sewers for adoption – standards agreed between sewerage companies and developers to specify allowable sewer dimensions and characteristics to allow adoption of responsibility

Soakaway – A sub-surface structure into which surface water is conveyed, designed to promote infiltration.

Soil – The terrestrial medium on which many organisms depend, which is a mixture of minerals (produced by chemical, physical and biological weathering of rocks), organic matter, and water. It often has high populations of bacteria, fungi, and animals such as earthworms

Source control – Surface water runoff dealt with at or close to its source.

Storm – An occurrence of precipitation: rainfall, snow, or hail

Sub-base – A layer of material on the subgrade that provides a foundation for a pavement surface.

Sump – A pit that can be lined or unlined and is used to collect water and sediments before being pumped out.

Surface water – Water which occurs on the land surface. e.g. ponds, lakes watercourses, standing water...etc.

Sustainable Drainage Systems (SuDS) – A sequence of management practises and control structures often referred to as SuDS, designed to drain water in a more sustainable manner than some conventional techniques. SuDS processes are designed to replicate natural drainage systems which improve water quality and amenity as well.

SuDS approval certificate – A sign off certificate issued following approval of the drainage design by the authorising authority, required in order to commence construction.

SuDS performance certificate – A sign off certificate issued following the 12 month maintenance period immediately after construction. If the SuDS system has been constructed and maintained in accordance with the approved design within the first 12 months of its construction, the authorising authority will issue a SuDS Performance Certificate to confirm that the constructed system complies with the agreed design.

Swales – A swale is a linear shallow channel which can convey runoff from one place to another, holding water and, ground conditions permitting, infiltrating water to the ground. Swales can be used in conjunction with other SuDS features to link components. For example, a swale could link areas of permeable pavement and rain gardens to retention or detention ponds.

Treatment – Improving the quality of water by physical, chemical and/or biological means

Water cycle – The cycle of processes by which water circulates between the earth's oceans, atmosphere, and land, involving precipitation as rain and snow, drainage in streams and rivers, and return to the atmosphere by evaporation and transpiration.

Watercourse – All types of passages in which water flows i.e. rivers, streams, ditches, drains, culverts, dykes and sluices.

Wetlands – Are open areas of shallow water creating habitats and storage for excess water as well as water quality and biodiversity benefits.

Weir – Horizontal structure to a predetermined design height which controls flow.

B

Appendix B
SuDS Checklist

B | Appendix B SuDS checklist

B.1. Design Checklist (undertaken by LLFA as a Statutory Consultee on SuDS or District Drainage staff)

Planning Approval Stage	Level of Details Required
Outline Planning Application	Conceptual Design Objection or approval with Drainage Condition
Full Planning Application	Outline Design Objection or approval with Drainage Condition
Discharging Drainage Condition	Detailed Design Detailed design and agreement and SuDS maintenance to be approved and discharged by LPA

B.2. Planning Checklist (undertaken by Planners)

Planning Approval Stage	Done/Not Done
Outline Planning Application - LLFA approved drainage with drainage condition	
Full Planning Application - LLFA approved drainage with drainage condition	
Discharging Drainage Condition - LLFA approved detailed design maintenance of SuDS and Recommended discharge of the Drainage Condition by LPA	
Inspection of constructed SuDS undertaken	
Maintenance Condition in place attached to planning	
Maintenance Condition discharged following construction and Maintenance Company in place (or information provided to private homeowners of future SuDS)	

B.3. Pre-application Design Checklist

Provide brief explanation of SuDS and drainage philosophy of the site, along with preliminary runoff rate and volume calculations.
Provide a conceptual sketch with drainage elements and flow routes

	Item	Done/Not done	Comment
Strategy in Place	Strategic approach to managing flood risk and surface water in place and a clear explanation of the SuDS proposal is given		
	Existing site surface water drainage established and all natural flow routes through development are defined		
	Difficult site conditions identified and mitigation proposed if required: • Contaminated soil • High groundwater table • Sloping site • Very flat site • Unstable subsurface rocks or soil workings • Sites with very deep backfill • SuDS on floodplains		
Discharge Points	Proposed discharge points confirmed and their locations (whether to ground, watercourse, public sewer or other) for all design return period events		
	The destination of runoff is prioritised into the ground, watercourses or the sewers as a last resort		
Management Train	Source control measures are identified		
	Site or regional control measures identified (if any)		If site and regional control are proposed, it triggers designation requirement * please see process chart for SuDS enforcement via FWMA route

	Item	Done/Not done	Comment
Attenuation	Locations for attenuation storage are identified with priority given to above ground methods		
	Interception storage is identified for pollution control		
	Long term storage locations are identified		
Environmental Aspects	Landscape and ecology criteria are defined		
Final Check	The SuDS philosophy objectives have been met in the overall design: Control of flooding Prevention of pollution Benefit for the community Wildlife opportunities		

Minimum requirements: All the above need to be provided in order to recommend planning approval with conditions. The conditions will be discharged once all of the relevant information/action has been submitted/enacted and approved by the LPA.

B.4. Outline Design Checklist

Provide all evidence for conceptual design. In addition to that:

- Provide evidence of approximate sizing of storage volumes and flow controls and agreements in principle for discharging connections (drawings and documents to support the evidence as appropriate)

	Item	Done/Not done	Comment
Supporting documents	Drainage design criteria agreed with Gloucestershire Council and local planning authority		
	Design flow reduction in accordance with national standards and the guidance set out in this document		
	Existing site surface water drainage infrastructure and ownership established		
	Consents have been obtained from the Environment Agency for any structures within 9 meters of a main river, from the LLFA for any structure with the potential to affect flows in an ordinary watercourse, or with Sewerage Undertaker for any connections to the public sewer		
	Evidence to justify moving down the SuDS hierarchy, where proposed SuDS solution appears to be less then optimal		
Drawings	Location and extent of the SuDS installation features and drainage system provided		
	Appropriate SuDS components have been used to manage runoff		
	The development has been split into sub-catchments to manage runoff in manageable parts		
	The existing flow paths are modified to provide low flow routes and overflows		
	Source control and interception storage are provided and their volumes defined – no runoff allowed from the site for events up to 5mm		
	Attenuation storage is provided and the volumes defined – storage for 1 in 30 years and 1 in 100 years taking into account climate change		

	Item	Done/Not done	Comment
	Long term storage is provided and the volumes defined for 1 in 100 years return period, 6 hour duration event. Volume released to infiltration or discharged at local discharge rates or a maximum rate of 2l/s per hectare or 5l/s, whichever is greater. Above ground attenuation systems to drain at a rate of 50% within 24 hours.		
SI tests	Ground conditions identified: Soil stability, presence of contaminated soil, geology, infiltration potential		
	If infiltration is not proposed, then sufficient evidence should be supplied to support the reason for not using infiltration. If infiltration is proposed, evidence and interpretation of percolation tests are presented.		
	If no evidence presented to secure that way of discharging surface water, then an alternative outfall should be identified in case forthcoming tests show inadequate infiltration features, environmental designations, etc		
	Identify any environmentally sensitive receiving water bodies for the runoff and demonstrate measures to safeguard the requirements imposed – groundwater protection zones, archaeological		

Minimum requirements: All the above need to be provided in order to recommend planning approval with conditions. The conditions will be discharged once all of the relevant information/action has been submitted/ enacted and approved by the LPA

B.5. Detailed Design Checklist

	Item	Done/Not done	Comment
Pre-development	Drainage catchment areas (showing permeable and impermeable areas)		
	Existing site surface water infrastructure condition, performance and identified and demonstrated that proposal do not conflict with the existing flow regimes, agreement for discharge		
Post-development	Drainage catchment areas (showing permeable and impermeable zones clearly defined) and any phasing details connections in place		
	Existing and proposed site sections and levels		
	Drainage pathways reflect natural flow patterns		
	Flow control structure are defined and sized on all attenuation features to ensure operation and maintenance when required. These can be accessed, maintained effectively and safely and are visually acceptable		
	Interception, attenuation and long term storage volumes are provided		
	Long term storage is provided and the volumes defined for 1 in 100 years return period, 6 hour duration event. Volume released to infiltration or discharged at local discharge rates or a maximum rate of 2l/s per hectare or 5l/s, whichever is greater.		
	Outfall and flow control structures sized with relevant agreements in place		
	Evidence that the site and SuDS will not become compromised by flooding from other sources and retains its capacity during the design rainfall events (evidence to follow from a flood risk assessment)		
	The method of managing the surface water and ground water during construction phase in the context of flood risk management		
	Flow routes for all conveyance channels are defined, with explanation of overland flow routes for exceedance and low flows		
	SuDS should be designed for the site as whole, i.e. including highways. SuDS serving highways will be assessed as part of the overall drainage strategy for the site		
	Long and cross sections for the proposed drainage system and finished floor levels of buildings		
	Construction details of flow control and SuDS structures provided		
	Infiltration tests undertaken following national standards to enable assessment (if infiltration is proposed)		
	The methods during construction implemented to avoid the changes to the nature and free draining characteristics of the soil (i.e. avoidance of heavy machinery over areas that will be using infiltration SuDS).		

	Item	Done/Not done	Comment
	A backup plan for exceedance flows exists which deals with failure (blockage etc.) of the SuDS		
	The proposed construction and surface treatment materials		
	The landscape integrates the SuDS		
	Landscape planting plans provided		
Calculations	The hydraulic criteria are met – flow rates and storage volumes		
	Appropriate supporting calculation demonstrate conformity with the design criteria agreed		
Environmental Aspects	Identify any proposed split of the SuDS between private (cartilage) and public (open space or highway) land Propose multi-functional use of SuDS space to meet community and environmental requirements wherever possible (use of green infrastructure) and the potential contribution of the surface water management system to the development design objectives for sustainability (including climate resilience)		
Risk and H&S	A Designer's Risk Assessment of the works including construction, operation and maintenance, public risk assessment during design life and demolition (CIRIA SuDS Manual update RP992/17)		Assessed by LPA
	The health and safety measures meet industry standards		Assessed by LPA
Construction Plan	A Construction Plan is in place • construction processes to protect the SuDS functionality (including the provision of temporary drainage systems); • Programming to protect the SuDS functionality; • Inspection and maintenance schedules, material tool and initial cost estimates; • maintenance access points, easements and outfalls; and • Storage and disposal arrangements for any arising, with supporting calculations showing how any such quantities have been assessed.		Assessed by both LLFA and LPA

	Item	Done/Not done	Comment
Maintenance Plan	A Maintenance Plan will be required by the Local Planning Authority. The maintenance plan and management strategy will not be subject to assessment and advice from the LLFA • A description of the system and how each part of the system is expected to work; • Management objectives for the site; • Maintenance access points, easements and outfalls; • storage and disposal arrangements for any arising, with supporting calculations showing how any such quantities have been assessed, • An estimate of annual maintenance costs broken down by each maintenance activity. The submitted cost breakdown should demonstrate that it is derived from the quantities described in e), above, • A maintenance inspection checklist to describe the inspection regime for the finished system which will enable its performance to be monitored throughout its design life, • A Health & Safety (H&S) Plan shall be submitted for large or complex applications as such works are likely to require a H&S Plan as a regulatory requirement under • the Construction Design and Management Regulations, • Developer/Applicant to provide the final full postal address of the properties subject to the SuDS application. This shall include the post code. • The maintenance of the SuDS is simple, cost effective and confirmed in a management plan • Plans for adequate maintenance arrangements are in place		
Communication Plan	A communications plan will not be subject to assessment and advice from the LLFA • construction processes to protect the SuDS functionality (including the provision of temporary drainage systems); • Programming to protect the SuDS functionality; • Inspection and maintenance schedules, material tool and initial cost estimates; • maintenance access points, easements and outfalls; and • Storage and disposal arrangements for any arising, with supporting calculations showing how any such quantities have been assessed.		

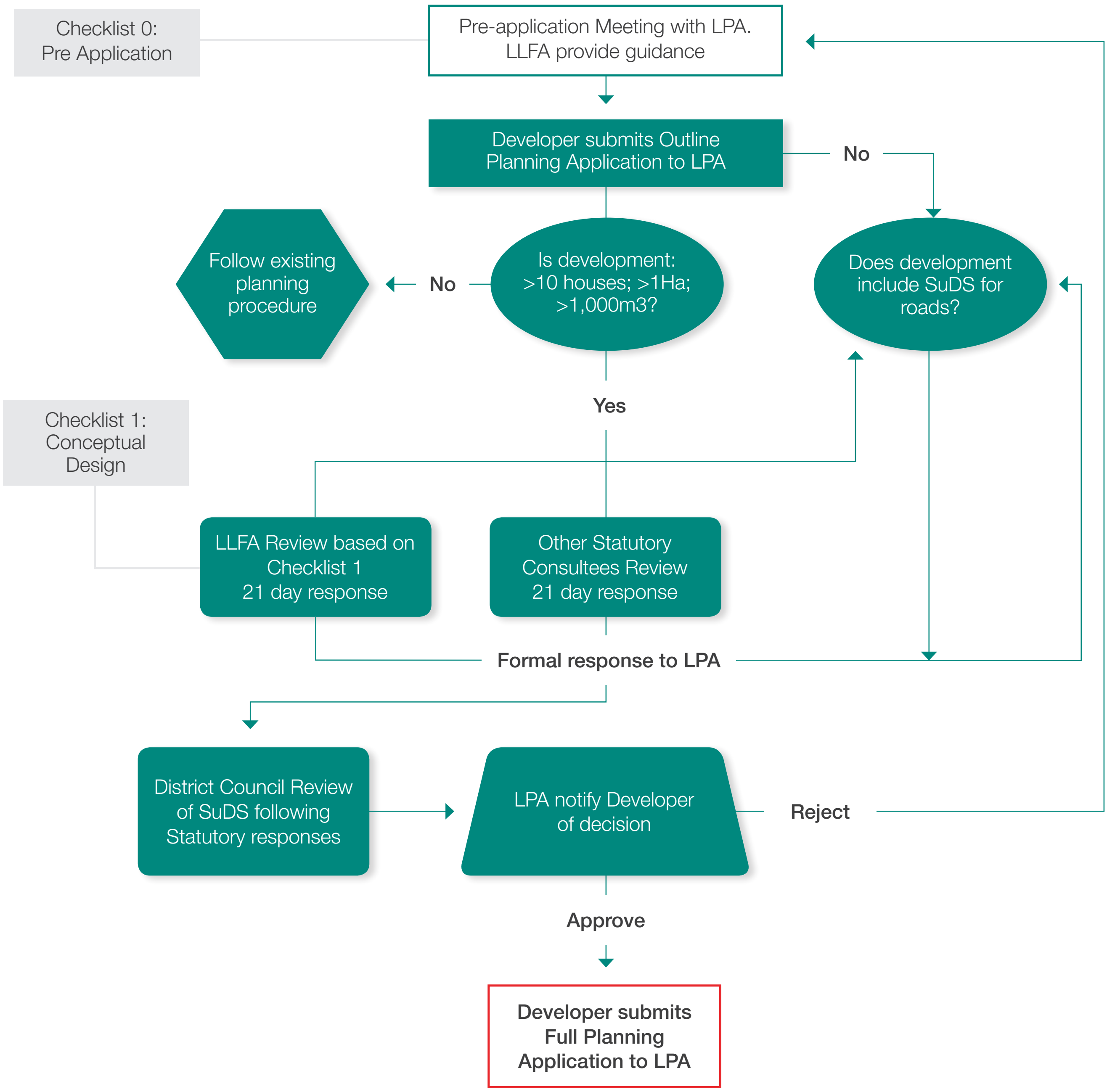
Minimum requirements: All the above need to be provided in order to recommend planning approval with conditions. The conditions will be discharged once all of the relevant information/action has been submitted/enacted and approved by the LPA

C

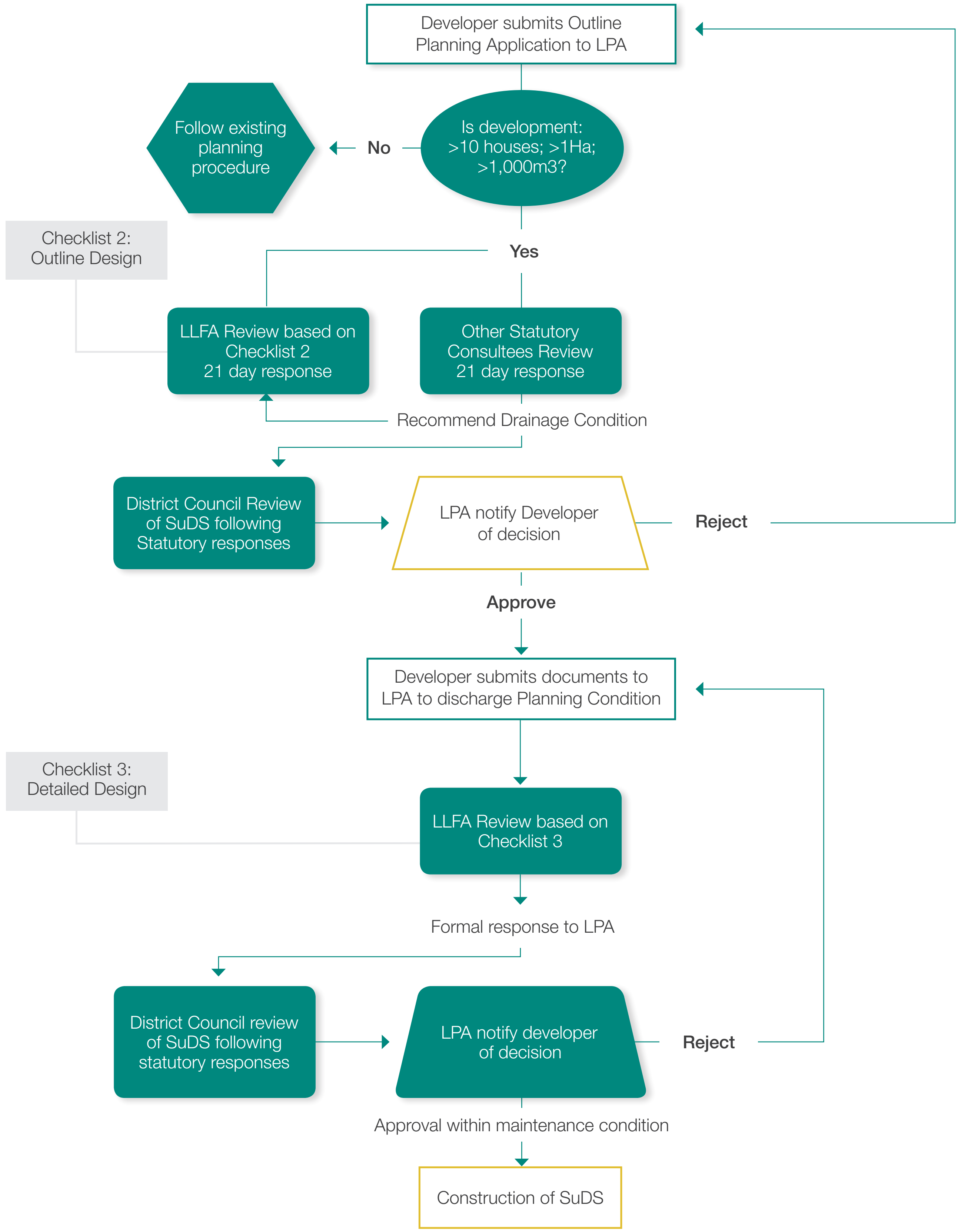
Appendix C
Planning Process

C | Appendix C Planning Process

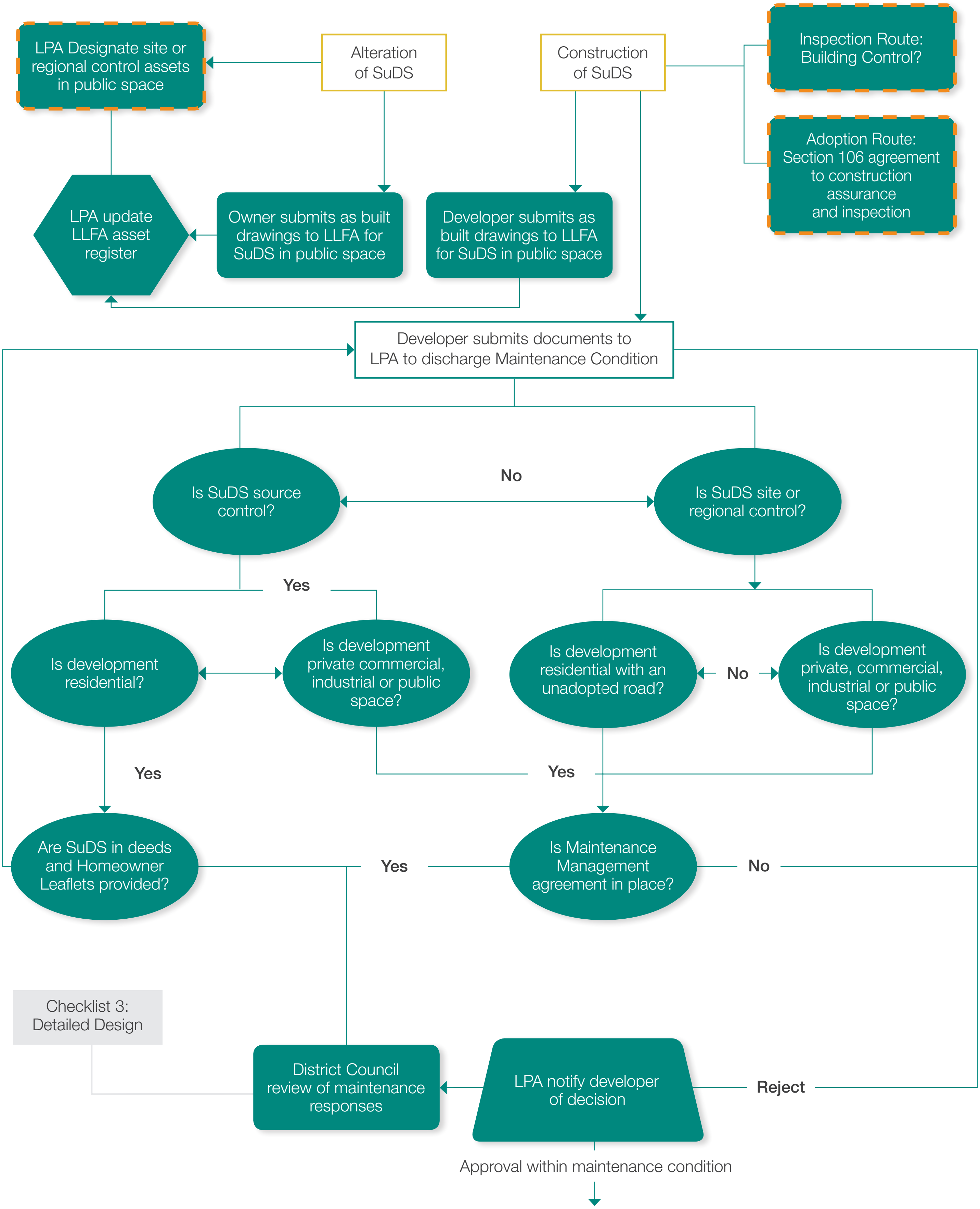
C.1. Pre-application and Outline Planning Process



C.2. Full Planning Process and Discharge of Drainage Conditions



C.3. Discharge of Maintenance Conditions



D

Appendix D References & further guidance

D Appendix D References & further guidance

This guide has been developed from a variety of sources, most notable the CIRIA SuDS manual (C697). You are directed to that publication, and the following publications, for further, more detailed, information.

D.1. Acts of Parliaments

Great Britain. Floods and Water Management Act 2010: Elizabeth II. Schedule 3. London: The Stationery Office; 2010.

D.2. Statutory Instruments

The Sustainable Drainage (Procedure) (England) Regulations 2012. Consultation draft SI XXXX. London: The Stationery Office; 2012.

The Sustainable Drainage (Appeals) (England) Regulations 2012. Consultation draft SI XXXX. London: The Stationery Office; 2012.

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Environmental Permitting Regulations (England and Wales) Regulations 2010. SI 675. London: The Stationery Office; 2010.

D.3. Reports

British Standards Institution (ed.) Code of Practice for surface water management for development sites. British Standards Institution. BS8582.2013.

British Standards Institution (ed.) Trees in relation to design, demolition and construction. British Standards Institution. BS5837

Kellagher. Rainfall runoff management for developments. Environment Agency. SC030219. October 2013.

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D.4. Book: print

Pratt, Wilson and Cooper. Source control using constructed pervious surfaces. Hydraulic, structural and water quality performance issues. Report C582. London. CIRIA. 2001

Wilson, Bray and Cooper. Sustainable drainage systems. Hydraulic, structural and water quality advice. Report C609. London. CIRIA. 2004.

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Balforth, Digman, Kellagher and Butler. Designing for exceedance in urban drainage – good practice. Report C635. London. CIRIA. 2006.

Newton, Gedge, Early and Wilson. Guidance on the use of green roofs, green walls and complementary features on buildings. Report C644. London. CIRIA. 2007.

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Woods-Ballard, Kellagher, Martin, Jefferies, Bray and Shaffer. Site handbook for the construction of SUDS. Report C698. London. CIRIA. 2007

D.5. Book: online / electronic

Graham, Day, Bray and Mackenzie. Sustainable drainage systems – maximising the potential for people and wildlife. [Online] RSPB & WWT. 2012. Available from: **www.rspb.org.uk/Images/SuDS_report_final_tcm9-338064.pdf. [Accessed 6 February 2015].**

HR Wallingford. The SuDS Manual Updates. Reports RP992/15 to RP992/31. [Online] CIRIA. 2012. Available from: **http://www.susdrain.org/resources/SuDS_Manual.html. [Accessed 6 February 2015].**

National SUDS working group. Interim code of practice for sustainable drainage systems. Report RP992/15. [Online] CIRIA. July 2004. Available from: **http://www.susdrain.org/files/resources/other-guidance/nswg_icop_for_SuDS_0704.pdf. [Accessed 6 February 2015].**

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Department of Transport. Manual of Contract Documents for Highway Works (MCHW). Ref [Online] DoT. May 2008. Available from: **https://www.gov.uk/standards-for-**

highways-online-resources#the-manual-of-contract-documents-for-highway-works. [Accessed 6 February 2015].

Building Research Establishment. Soakaway design. Digest 365 [Online] BRE. 2003. Available from: **http://www.brebookshop.com. [Accessed 6 February 2015].**

Gloucestershire's Local Nature Partnership [Online]. 2002. Available from: **http://gloucestershirebiodiversity.net/. [Accessed 6 February 2015].**

D.6. Webpages / websites

Defra. National standards and associated guidance [Online]. Available from **https://www.gov.uk/government/organisations/department-for-environment-food-rural-affairs [Accessed 6 February 2015]**

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