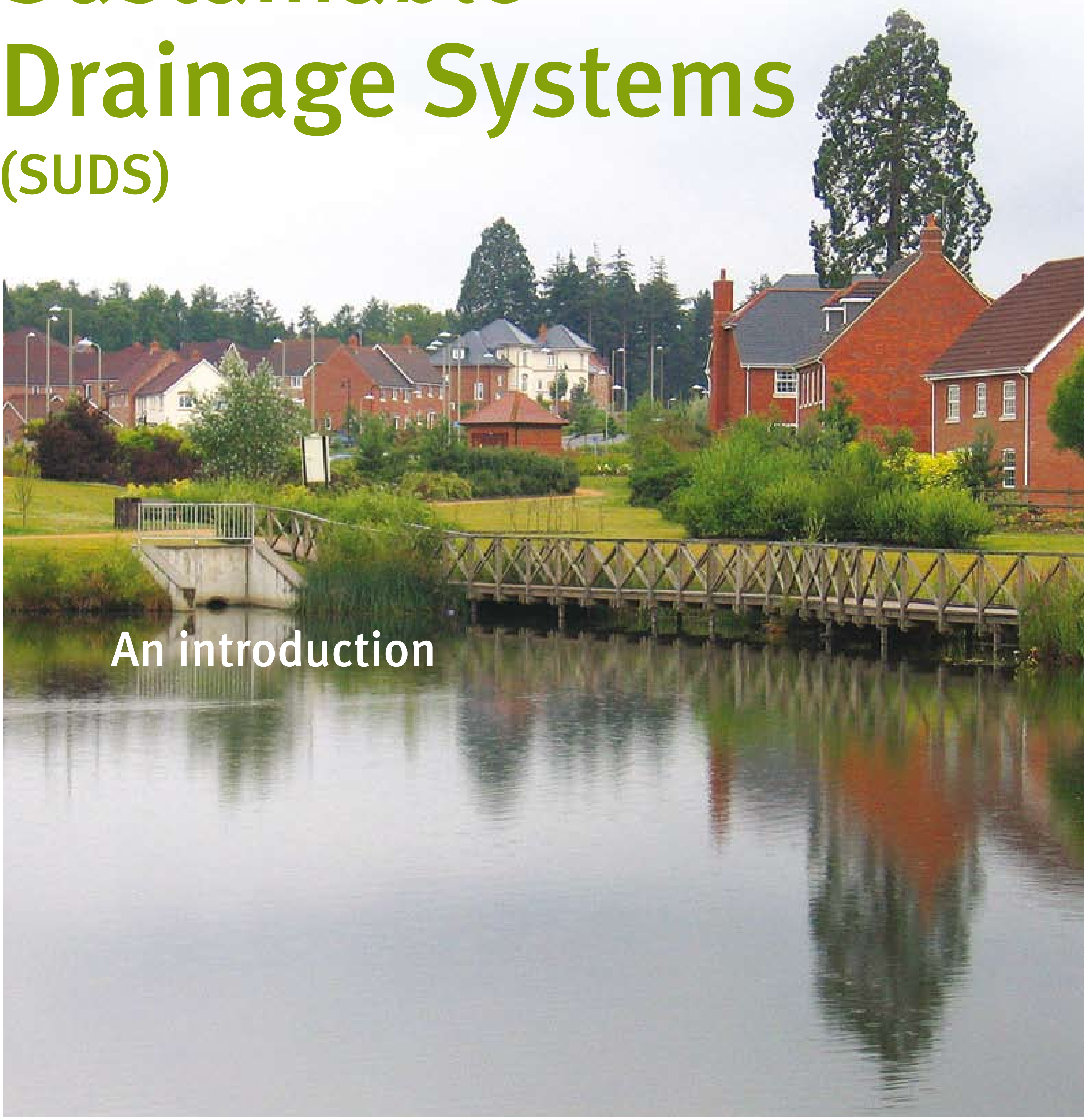
Environment Agency

# Sustainable Drainage Systems (SUDS)



## An introduction

We are the Environment Agency. It's our job to look after your environment and make it a better place – for you, and for future generations.

Your environment is the air you breathe, the water you drink and the ground you walk on. Working with business, Government and society as a whole, we are making your environment cleaner and healthier.

The Environment Agency – out there, making your environment a better place.

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# Surface water drainage – the need for change

**Surface water drainage from developed areas is increasingly affecting our river catchments. As development intensifies, so more water runs rapidly into rivers and less filters through the soil. This sealing of the ground can and does lead to localised flooding and water pollution, and will only get worse as our climate changes. We need a new approach to drainage that keeps water on site longer, prevents pollution and allows storage and use of the water.**

Sustainable Drainage Systems (SUDS) provide this alternative approach. These systems endeavour to mimic the natural movement of water from a development, reducing flood risk, improving water quality and often providing attractive features that can make towns and cities more desirable places to live in and enhancing the quality of life. In addition, the European Water Framework Directive requires us to manage water resources sustainably and to protect water quality. SUDS offer an integrated approach that could play a key part in delivering the Directive's requirements.

We need to act now to improve the management of water in the urban setting. We cannot allow new developments to add to the risks of flooding and pollution of our rivers and streams. Rather than seeing water in the built environment as a threat, we should take the opportunity to protect and use it more carefully. For new developments, and any re-development, we must seriously consider using SUDS and gaining the benefits for ourselves, for society as a whole, for industry and for wildlife.

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This document has been produced by the Environment Agency working with the Scottish Environment Protection Agency (SEPA) and the Environment and Heritage Service in Northern Ireland.

# Contents

# Introduction

**As our towns and cities have grown, green fields have been replaced by hard surfaces. Instead of soaking into the ground, rainwater is collected in pipes and carried as fast as possible to the nearest river or stream. This effect has become more pronounced with the increased pace of development. As a consequence, the Scottish Environment Protection Agency, the Environment and Heritage Service in Northern Ireland and the Environment Agency for England and Wales (referred to in this brochure as the Agencies) are working together to reduce pollution and flooding risk and to promote more sustainable drainage systems in Britain.**

We would like to highlight problems caused by conventional urban drainage systems and identify alternative approaches referred to as SUDS – SUstainable Drainage Systems (in Scotland, Sustainable Urban Drainage Systems).

We have been successful in controlling water pollution from major sources such as sewage treatment plants and factories. But there is a growing problem with diffuse pollution, which comes from a wide range of small sources in urban areas. These include drainage from roads, industrial and residential areas. Uncontrolled, rapid run-off from developments increases the risk of flooding from receiving watercourses and can damage the river habitat. It also decreases the amount of water soaking into the ground, reducing the water available for our use and to flow into our rivers.

Rain falling on these areas is normally drained to watercourses via surface water outfalls. These discharges are often thought of as being clean but in fact contain a range of contaminants including oil, organic matter and toxic metals. Cross connections of foul sewers into surface water drains are also common. Urban rivers are often severely degraded as a result.

The Salmon Brook in London is an example of an urban watercourse affected by urban drainage.

The environmental impact can be minimised through good design and practice. We aim to raise awareness of the environmental problems arising from conventional urban drainage and present design options that are effective in reducing them. It is part of the process of delivering more sustainable urban development.

Protecting rivers and groundwaters from the effects of these pollutants requires a new approach to drainage and a review of the need for treatment prior to discharge. A range of techniques known as Sustainable Drainage Systems are available to achieve this. These are a flexible set of options that allow a designer to choose the most suitable combination of techniques to fit the circumstances of a particular site. We also aim to provide you with an overview of the techniques that are available and show you where further information can be obtained.

The techniques described are effective for reducing the impact of surface water discharges. It is our policy to promote the use of SUDS and the importance of including the SUDS approach in all developments at the earliest possible stage. We are encouraging local planning authorities to include reference to SUDS in strategic and local plans. Developers should consider SUDS in their land purchase negotiations.

There is no need for the drainage from urban developments to damage our water resources. But, to protect our environment, we need the support and co-operation of a wide range of public and private organisations involved in urban development. These include planning and highway authorities, sewerage undertakers and developers. By working together, we can ensure that drainage from roads and urban areas is designed in a cost effective and more sustainable manner.

Well designed drainage systems can make a positive contribution to an attractive environment, as in this housing site in Dunfermline.

# Development, drainage and the legal basis for control

**Sustainable drainage can only be effectively implemented at a site if it is incorporated in a developer's plans at the earliest possible stage, not least because its use may influence land purchase and decisions on site layout.**

All proposals for development will require planning consent. The Planning System plays a major part in directing and shaping new developments as well as protecting and enhancing the environment. It therefore has a vital role in achieving sustainable development.

The Planning System is operated by local authorities. It has a legal basis supported by national planning policy guidance statements. The two main components are development plans and the consideration of individual planning applications through a development control process.

Local Development Frameworks (or Plans) set out the main considerations on which planning applications are decided. Development documents contained within them are of primary importance for shaping land use change. They provide an opportunity to prevent future problems arising as a result of development. In addition, local authorities may also produce separate site specific development briefs providing advice on a range of development issues, including appropriate means of surface water drainage. The Agencies and sewerage undertakers are usually consulted on major schemes and advise local authorities about appropriate surface water drainage systems and techniques. Specific requirements may be attached to any planning consent, as either a condition or as part of a legal agreement.

Local authorities will ask for an environmental assessment to be undertaken and an environmental statement to be produced for certain types of development. It is the responsibility of the developer to provide the statement; however, we and local authorities will offer guidance on drainage issues, particularly at the scoping stage.

Sustainable Drainage techniques were incorporated into the roadside service area on the M40 from the earliest planning and design stage. SUDS provided the most economic means of protecting the local watercourse from flooding and pollution.

The Agencies, sewerage undertakers and many local authorities are now committed to promoting SUDS, and planning policies are now being included in development plans. Developers should consult local authorities about planning policies on sustainable urban drainage. For example, Gloucester City Council have produced Supplementary Planning Guidance that promotes this approach, and a number of local authorities in Scotland, including West Lothian and Falkirk Councils, have adopted policies in local plans which support SUDS.

We may also regulate discharges of site drainage under the law on water pollution in addition to the development control process. The legal basis of water pollution control differs between Scotland, Northern Ireland and England and Wales. But in practice, the control of surface water discharges is achieved by the application of similar principles. The regulation of surface water discharges is a discretionary power and we seek to encourage the adoption of good practice. This would do away with the need for formal discharge consents for smaller discharges.

We can use Prohibition Notices to impose controls on unsatisfactory discharges. They can be used to lay down conditions or require a full application for a formal discharge consent in cases were there is a failure to agree suitable measures. Soakaway systems for surface water discharges are subject to control under Water Pollution Regulations including the Groundwater Regulations 1998 (where List I or List II substances are present). All discharges must be carried out in line with the appropriate Code of Practice.

## Examples of sites where SUDS have been applied

In England, an increasing number of sites have been constructed with a SUDS approach to drainage. These include several sites in South Gloucester including St Mary's RC School in Bradley Stoke where a range of techniques were employed including a pond which is being used as an educational resource. Surface water from the nearby Emersons Green housing development, to the north of Bristol, passes through a system of ponds and wetlands which provide an attractive amenity for the community.

In Northern Ireland, during the construction of the Newtownstewart by-pass, this pond was excavated to prevent the discharge of silt and oil during the earthworks phase. After completion of the road, and cleaning, it became a retention pond in the SUDS treatment train.

The BedZed residential and commercial development in Croydon, South London, uses permeable paving, green roofs and rainwater harvesting to reduce the impact of the site on the water environment. SUDS were a key element in the construction of the Meteorological Office in Exeter with its water feature that runs through the site and permeable paving in parking areas. Other sites include the Oxford motorway service area on the M40 at Wheatley, Oxfordshire and the Hopwood Park services on the M42.

A large number of sites in Scotland use SUDS. A wide range of techniques were used in the construction of the Dunfermline East Expansion (DEX). The area is characterised by small wetlands at individual sites and swales (shallow grass channels) that direct rain water to ponds built to retain water all year round.

In Northern Ireland, SUDS are being considered for a wide range of developments, including industrial sites and roads. The Newtownstewart by-pass, opened in 2002, was constructed using a SUDS approach to drainage. It incorporates filter drains and specially constructed ponds to maintain the high quality of the River Strule.

# The environmental impacts of urban drainage

## When the environment is modified by development, the effects can be seen in a number of ways.

### Water quality

Rain falling on impermeable surfaces rapidly picks up contaminants such as dust, oil, litter and organic matter. The impact of this material being flushed into a watercourse can be dramatic. High levels of silt blanket stream life and organic matter rapidly reduces oxygen levels in the water. Numerous studies of the polluting nature of such runoff have been made (1, 2). Life in receiving streams may be severely restricted as a consequence of repeated discharges. Fish that venture into them risk being suffocated in the event of a storm.

The quality of groundwater may also be affected where discharges soak into the ground. Chemical and oil storage spillages, and transport activities add to pollution in both watercourses and groundwaters. A further problem arises when people pour used oil, garden chemicals, car washing water and other liquid waste into drains, unaware that most surface water drains discharge directly to watercourses and soakaways. This adds to the polluting load.

A related issue is the connection of foul drainage, by accident or ignorance, to the surface water drains. Householders who have no idea that two drainage systems exist, often have their toilets, washing machines and dishwashers plumbed incorrectly.

> The increase in impermeable areas that accompanies development also results in less water being available for infiltration into the ground.

Too many urban rivers are both culverted and polluted by surface water discharges. This reduces water quality and biodiversity in our urban areas.

### Flooding

Natural drainage patterns are disrupted as land is developed. In most cases, the amount of impermeable cover will increase as a result of development. Traditional drainage systems are designed to remove rainfall from these impervious surfaces as quickly as possible. This causes higher flow rates for shorter periods (see Figure 1) and can result in flooding further downstream. Balancing ponds, underground storage tanks or similar measures are often required to compensate for this.

### Water resources

The increase in impermeable areas that accompanies development also results in less water being available for infiltration into the ground. This can reduce the volume of water stored in the ground, lowering groundwater levels and reducing the amount of groundwater available to feed into streams and rivers.

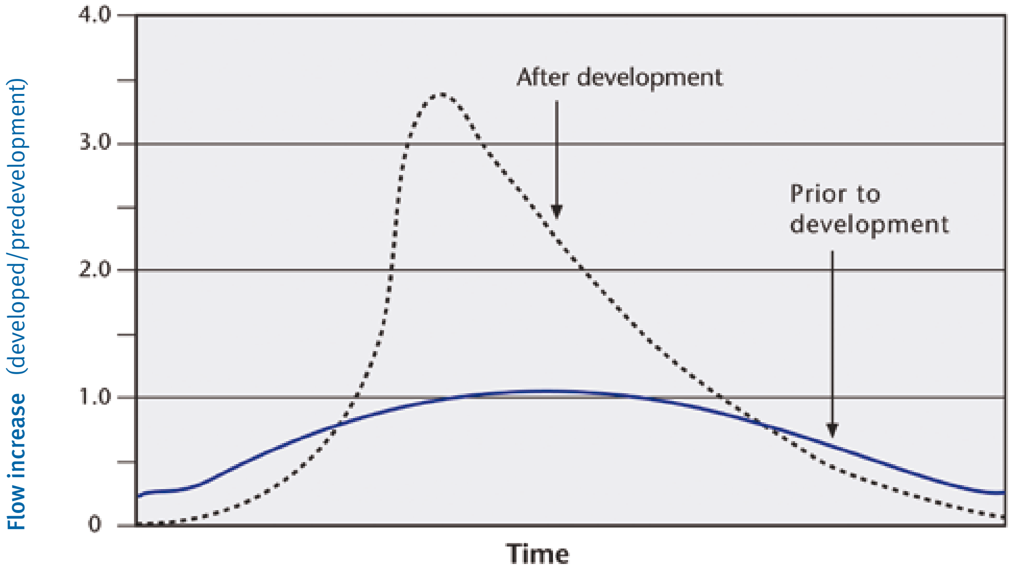



**Figure 1** Impact of urbanisation on runoff quantity

Flooding may occur for a number of reasons, including inadequately designed surface water drainage systems.

Car parks with impervious surfaces are a common feature in the urban environment. Permeable paving can be used to reduce the impact of car parks on flooding and water quality, without compromising the car park's utility. The design and construction of porous surfaces must be in accordance with the manufacturer's specification.

## Habitat

Changes in water flow patterns such as high flow rates for short periods and reduced flows at other times can dramatically alter the river habitat. Increased flow rates can erode river banks and beds, resulting in material being deposited further downstream. In some areas, rivers have been straightened and confined in concrete to control erosion but this has resulted in the loss of bankside habitat. These changes mean that rivers in urban areas are often unable to support a variety of wildlife and plants and become eyesores.

One further adverse effect of conventional drainage systems is amphibians getting trapped in road gullies. Frogs and newts often fall into road gullies and are unable to escape.

# Sustainable Drainage Systems

## Many existing drainage systems are damaging the environment and are not sustainable in the long term. Techniques to reduce these effects have been developed and are collectively referred to as Sustainable Drainage Systems/ Sustainable Urban Drainage Systems (SUDS).

Sustainable drainage is a concept that makes environmental quality and people a priority in drainage design, construction and maintenance. The SUDS approach includes measures to prevent pollution, reduce surface water runoff at source and provide a range of physical structures designed to receive the runoff.

Taking simple steps to educate people and providing facilities such as dog litter bins and oil recycling banks can help prevent pollution. Source control measures include permeable surfaces and rainwater reuse systems such as rainwater butts. Physical structures include swales, ponds and wetlands which should be located as close as possible to where the rainwater falls. This reduces the peak flow from the site and extends the duration of the runoff (attenuation) so reducing the need for larger systems downstream.

They may also be used to treat water prior to discharge, using the natural processes of sedimentation, filtration, adsorption and biological degradation.

There are many SUDS design options to choose from and they can be tailored to fit all types of development, from hard surfaced areas to soft landscaped features. They can also be designed to improve amenity and biodiversity in developed areas. For instance, ponds can be designed as a local feature for recreational purposes and to provide valuable local wildlife habitat nodes and corridors.

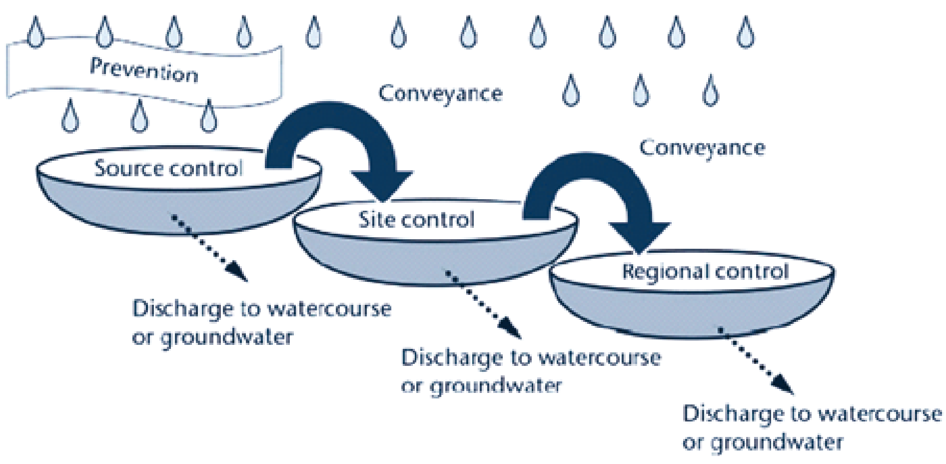



Figure 2. Surface water management train: addressing runoff quality at all stages of the drainage system.

**The surface water management train approach should be incorporated at all new development sites as a way to implement measures to attenuate flow and reduce pollution.**

This variety of options enable designers to think about local land use and the needs of local people when undertaking drainage design. It takes into account the traditional engineering components of designs such as peak flow and system capacity. The surface water management train is a useful concept in the development of a drainage system (see Figure 2). Just as in a natural catchment, a combination of drainage techniques can be used to change the flow and the quality of the runoff in stages.

SUDS provide a number of options for draining an area. The designer or engineer is free to choose the best option(s) for any given site. SUDS fall into three broad groups which aim to:

1. Reduce the quantity of runoff from the site (source control techniques);

2. Slow the velocity of runoff to allow settlement filtering and infiltration (permeable conveyance systems);

3. Provide passive treatment to collected surface water before discharge into groundwater or to a watercourse (end of pipe systems).

The surface water management train approach should be incorporated at all new development sites as a way to implement measures to attenuate flow and reduce pollution. It is not usually necessary or desirable to use designs from the three groups of systems listed above to solve a specific drainage problem. These systems may be incorporated into drainage designs to take a portion of the runoff whenever it is not feasible to use SUDS for draining a whole site. Some SUDS techniques fall into more than one group. For example, attenuating flow and providing treatment.

In considering a drainage system, it is beneficial to work through the surface water management train shown in Figure 2.

1. The scope for minimising the quantity of water collected should be considered first, since this determines the sizing of downstream systems and can provide the greatest savings. Rainwater harvesting, the collection and storage of roofwater for reuse in flushing toilets or watering plants and landscaped areas should be considered. If the site groundwater protection considerations and soil conditions will permit it, infiltration would be a desirable option. Both should be considered at an early stage.

2. Collected runoff should be removed from the site in a way that reduces the level of pollution and allows further infiltration and volume loss.

3. Finally, and only if necessary, further flow attenuation and passive treatment can be installed to control flood risk and improve water quality before final discharge to a watercourse.

Roadside swale, Whitburn, West Lothian.

## Developers need to include SUDS in their plans at the earliest stages of the process to ensure that they are successfully designed, built and maintained.

SUDS offer a combination of benefits that conventional drainage systems do not provide. For instance:

- SUDS can protect and enhance water quality and biodiversity in local streams;
- SUDS may maintain or restore the natural flow regime in streams;
- SUDS may protect people and property from flooding, now and in the future;
- SUDS can protect watercourses from pollution caused by accidental spillages and misconnections;
- SUDS may allow new development in areas where sewerage systems are already at full capacity, encouraging new development within existing developed areas and protecting greenfield sites;
- SUDS can be designed in a way that is sympathetic to their environmental setting and the needs of the community;
- SUDS can allow natural groundwater recharge where this is considered appropriate;
- SUDS may also simplify construction. Permeable paving will allow for the building of flat car parks, stopping puddles from forming and removing the need for gully pots. The need for pumps can be eliminated in low lying areas.

Developers need to include SUDS in their plans at the earliest stages of the process to ensure that they are successfully designed, built and maintained. It is important for developers to consult with planning authorities, highway authorities, sewerage undertakers and regulators (as appropriate), early in the development process, when SUDS options are being considered.

A range of organisations concerned with SUDS have worked with the Construction Industry Research and Information Association (CIRIA) to produce technical design guidance on SUDS. The SUDS Manual was published in 2007 and provides comprehensive coverage of SUDS issues. (3) The Scottish Environment Protection Agency (SEPA) and the Environment Agency have also collaborated with the Urban Design Alliance and the Institution of Civil Engineers to produce a DVD (4) entitled 'Designs that hold water – sustainable drainage systems explained'. This explains the problems associated with existing drainage systems and identifies the benefits of SUDS using case studies from the UK.

The following pages describe in more detail examples of these SUDS techniques.

# Source control and prevention techniques

**Source control and prevention techniques are designed to counter increased discharge from developed sites, as close to the source as possible and to minimise the volume of water discharged from the site. This offers the benefits of reduced flood risk and improved water quality. It helps to restore underground water resources and maintain flows in surface watercourses during dry weather.**

Some of these techniques are familiar as in the use of rainwater-butts in gardens to collect the runoff from a roof. The water-butt fills when it rains (the water is collected at/near the place of the rainfall, hence it is collected at source), and the water is used on the garden during dry periods. This principle is applied for all source control techniques. But care is needed with infiltration techniques. In some circumstances, for example on contaminated land, close to water supply boreholes or where the groundwater is vulnerable to pollution, infiltration may not be appropriate. We recommend that developers seek our advice.

Water is collected and drained beneath the permeable paving in this residential area (Photograph provided by Oxfordshire County Council).

Good site design will maximise the use of areas such as gardens and parklands, which will continue to drain naturally and minimise paved areas. Where paving is required for drives, access roads and car parking areas, permeable materials can reduce the need to collect runoff in drains. Cost savings can be made through the reduction in size, or even elimination, of off-site surface water sewers.

Providing there is no danger of increasing downstream flooding risks, such installations need not be designed to receive very large storms. A system that is designed to accept a twice per year storm before an overflow or bypass takes effect will still have significant environmental benefits. It will greatly reduce the frequency of discharge, provide protection from the pollution resulting from the flushing of pollutants from paved areas (the 'first flush') and delay the time of discharge. This will allow time for the flow in the receiving watercourse to increase. In most urban developments, downstream flooding will be a concern and additional storage will need to be provided.

The option of allowing a part of a development site to be flooded under some circumstances should also be considered. It may be acceptable to allow shallow flooding of a car park for short periods once or twice a year rather than building a much larger drainage system to cater for such infrequent events.

With good source control techniques, runoff from new developments need have little impact on the natural movement of water within a catchment.

## Green roofs

Green roofs can be used to reduce the volume and rate of runoff so that downstream SUDS and other drainage infrastructure can be reduced in size. They also have water quality and habitat benefits. They are widely used in Germany and other European countries and are being used more often in the United Kingdom. Many conventional flat roof systems used in industrial buildings could be converted to green roofs without exceeding design loadings. There are additional benefits; green roofs improve insulation and extend roof life.

## Permeable pavements

Permeable pavement is an alternative to conventional paving in which water filters through the paved structure rather than running off it. Both the surface and the sub-grade need to be designed with this function in mind. Water may be allowed to infiltrate directly into the subsoil where conditions are suitable. Alternatively, it can be held in a reservoir structure under the paving for reuse, infiltration or delayed discharge. The permeable paving can be made from materials such as gravel, grasscrete, concrete blocks designed for the purpose or porous asphalt.

The photograph below shows a supermarket car parking area where a porous covering overlies a sealed storage reservoir filled with graded stone. Rainwater passes through the pervious surface and is stored in the storage reservoir, which is about one metre deep. The stored water can then slowly discharge to a nearby stream. The access routes have been constructed using conventional asphalt, which can be clearly seen in the photograph.

Porous paving of the parking area, at a supermarket in Wokingham, Berkshire, is clearly visible.

Overflows can be constructed on all these systems wherever surfaces must be kept free of water at all times or where the base needs to be sealed to protect the aquifer. Even if the overflow operates, storage and filtering of the runoff water has occurred, and environmental benefits accrue. The overflow can lead into a permeable conveyance system to increase further the benefit and reduce the need for pipe systems.

Permeable paving is effective in removing pollutants. High removal rates for sediments, trace metals and organic matter have been reported and a reduction in nutrients has also been measured.

Permeable pavements need to be protected during installation from the excessive mud that is usually present on construction sites. Design guidance on permeable pavements is available from CIRIA (5).

The parking bays at this motorway service area has been built with porous blocks. The rainfall from the tarmac access roads runs onto these bays.

## Rainwater harvesting

Rainwater from roofs and hard surfaces such as car parks can be stored and used in and around properties. The simple rainwater butt, used for watering plants, is a familiar method of storage.

There has been a recent growth in the use of the collected water for a range of non-potable uses, particularly for flushing toilets. Stored water is generally held in a suitably sized underground tank and pumped to the point of use. A mains water supply is usually provided as a back-up if rainwater is not available.

## Infiltration trenches

An infiltration trench is a shallow, excavated trench that has been lined with a geotextile and backfilled with stone to create an underground reservoir. Stormwater runoff flowing into the trench gradually infiltrates into the subsoil. An overflow may be required for extreme rainfalls that exceed the capacity of the reservoir.

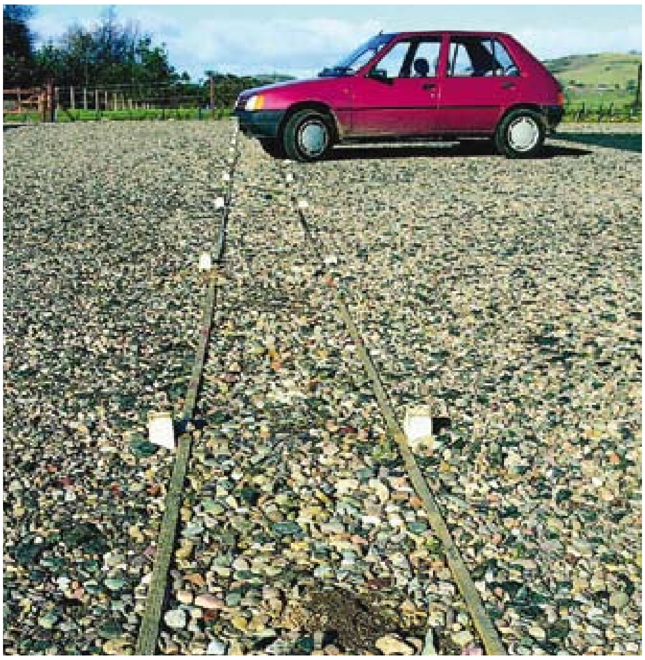
The performance of the trench depends largely on the permeability of the soil and the depth to the water table. Infiltration trenches usually serve small catchment areas up to 2-3 hectares in common with other source control techniques. The closer they are to the source of the runoff the more effective they will be. The operational life of the trench may be enhanced by providing pre-treatment for the inflow, such as a filter strip, gully or sump pit, to remove excessive solids. Regular maintenance will be required for most pre-treatment designs.

This infiltration trench is incorporated into the landscape areas on a road embankment. The trench has an overflow into a stream.

Infiltration trench at the edge of a minor road. Water is taken into the trench via off-let kerbs.

Infiltration trenches that are properly constructed and maintained can significantly reduce levels of solids, coliforms, trace metals and organic matter. Levels of nutrients can also be reduced.

Design guidance for infiltration systems can be obtained from the Building Research Establishment (6) and CIRIA (7).



This gravel car park area in Fife has an inflitration trench in the centre. Water soaks into the ground, but during high rainfall, the overflow takes excess flow from the trench to a nearby stream.

## Infiltration basins

Infiltration basins are shallow features where stormwater runoff is stored until it gradually infiltrates through the soil of the basin floor. An overflow may be required for extreme rainfall events which exceed the capacity of the basin.

The performance of the basin depends largely on the permeability of the soil and the depth to the water table. Infiltration basins can serve larger catchment areas than infiltration trenches because a larger volume of water can be stored on the surface. They can typically serve catchments of up to 10 hectares.

As with the infiltration trench, the life span of the infiltration basin may be increased by providing runoff pre-treatment, such as a filter strip, gully or sump pit to remove excessive solids. Larger basins need to be designed carefully to prevent sediment being washed out during storms. Regular maintenance will be required for most pre-treatment designs.

Properly constructed and maintained infiltration basins can be expected to remove a large proportion of solids and a lower proportion of soluble pollutants.

# Permeable conveyance systems

**Permeable conveyance systems move runoff water slowly towards a receiving watercourse allowing storage, filtering and some loss of runoff water through evaporation and infiltration before it reaches the discharge point. The main types of permeable conveyance systems are underground systems such as filter drains (or French drains) and surface water swales.**

## Filter (or French) drains

A filter drain is a trench lined with a geotextile and filled with gravel into which runoff water is led, either directly from the drained surface or via a pipe system.

The gravel in the filter drain provides some filtering of the runoff, trapping sediment, organic matter and oil residues that can be broken down by bacterial action through time. The runoff rate is reduced, and runoff storage is also provided. Stored water can also pass through the geotextile membrane and some filter drains need not lead to a watercourse at all.

A filter drain at the edge of a road in Stirling. There are no kerbs or gullies incorporated into the design.

Swale on A8000 near Edinburgh. No kerbs or gullies are required.

Filter drain systems have been widely used by the highway authorities for roads drainage and feature in the Design Manual for Roads and Bridges (8).

Hybrid infiltration systems and filter drains have been used for a variety of developments, including both residential and industrial sites.

## Swales

Swales are linear grass covered depressions which lead surface water overland from the drained surface to a storage or discharge system, typically using road verges. Unlike a conventional ditch, a swale is shallow and relatively wide. It provides temporary storage for storm water and reduces peak flows. They are located close to the source of runoff and can form a network within a development linking storage ponds and wetlands.

This picture shows a filter strip that has been integrated into the pond design in Livingstone. The gravel filter strip produces a rooting medium for plants between the two sections of the pond.

**Performance can be enhanced by placing check dams across the swale to reduce the flow rate which, in turn, reduces the risk of erosion in a swale**

A swale is dry during dry weather but in wet weather, rainwater flows into it along its length and moves slowly through the grass area. The grass slows down and filters surface water flows. Sediment is deposited while oily residues and organic matter are retained to be broken down in the top layer soil and vegetation. The underlying aquifer can be protected, if needed, by placing an impermeable lining under the swale below the soil.

During a rainfall event a proportion of the runoff can be lost from the swale by infiltration, and by evaporation and transpiration. Overflows can be provided to allow conveyance during periods of exceptionally heavy rainfall. Swales should be designed to be dry between storm events to enhance their pollutant removal capability.

Swales work best with small gradients both for their side slopes and along their length. Performance can be enhanced by placing check dams across the swale to reduce the flow rate which, in turn, reduces the risk of erosion in a swale. The pollution load can be considerably reduced even where swales discharge directly to a watercourse. In addition, where runoff is conveyed via surface channels, wrong connections become obvious and can be fixed without the need for expensive surveys.

Swales avoid the need for expensive roadside kerbs, gullies and related maintenance. They also reduce risk to amphibians such as toads and newts, which are often trapped in gully pots. Some regular maintenance is required to keep a grass swale operating correctly; chiefly, mowing during the growing season. The optimum grass length is around 150mm.

# Passive treatment systems

**Passive treatment systems use natural processes to remove and break down pollutants from surface water runoff. Small scale systems such as filter strips, can be designed into landscaped areas and are sited upstream of other SUDS. Larger, 'end of pipe' systems usually involve storage of water in constructed ponds where natural purification processes can be encouraged. Constructed wetlands and ponds also provide the opportunity to improve wildlife habitat in urban areas. Additionally, ponds can be made into amenity features for the local community.**

## Filter strips

Filter strips are vegetated sections of land designed to accept runoff as overland sheet flow. In order to be effective they should be 5-15 metres wide and they may adopt any natural vegetated form, from grassy meadow to small wood. The wider the strip and the more dense the plant cover the better the pollutant removal.

Filter strips are best employed at the upstream end of the drainage system, accepting runoff from small areas (up to 2 hectares) directly, for example, before it is concentrated in a drainage system. Road runoff can also be treated in this manner, provided the road/filter strip boundary is designed so that it does not become blocked by sediment or vegetation.

Drainage from a lorry park crosses a filter strip to an infiltration trench at this site in the Midlands.

Filter strips can be used effectively to remove excess solids and pollutants before discharge to an infiltration system. They may preserve the character of riparian zones and prevent erosion along stream banks by reducing flow velocities and spreading the flow across a wide area. They also provide an excellent wildlife habitat when used in this way.

## Detention basins

Detention basins are designed to hold back storm runoff for a few hours to allow solids to settle. Bypasses may be included to ensure the 'first flush' is detained. Detention basins drain via an orifice plate or similar hydraulic structure into a watercourse or surface water drainage system.

Detention basins are dry outside of storm periods. They are designed to retain flood events, reducing peak flows and limiting the risk of flooding.

The entire contents of the basin are drained down, and therefore they have a low level outlet orifice, which can lead to clogging by sediment. Careful location and design of the basin inlet and outlet prevents the washing out of sediment by high flows. This maximises the performance of the basin. The performance can also be enhanced by including small pools at the inlet and outlet to act as sumps to collect sediment.

Highway junctions provide land between slip roads that can be used for ponds or wetlands. In this case, land in the centre of a roundabout has been used as a detention basin, which releases rainwater at a fixed maximum rate, providing storage at times of intense rainfall.

## Retention ponds

Retention Ponds retain a certain volume of water at all times. This means that the unsightly exposure of banks of collected sediment can be avoided. It also improves the process of removing nutrients, trace metals, coliforms and organic matter. Allowance for a considerable variation in water level during storms should be incorporated in the design, so that a significant storage volume can still be provided.

The permanent water may be visually more attractive although elevated nutrient concentrations may result in algal blooms. To be successful as an amenity, a retention pond should have a catchment of at least 5 hectares and/or a reliable inflow of water in dry weather. Inlet and outlet sumps will, as for detention basins, improve performance by trapping sediment and preventing clogging of the outlet. Removal of collected sediment from the inlet sump may be needed although typically, this is not required at a frequency greater than once every seven years.

This pond provides an attractive feature for this development in Greenwich, London.

This pond is the final stage of the drainage system serving a major development at Elvetham, Hampshire.

Ponds can be fed by a swale system, a filter drain network or a conventional surface water system. The last option will result in much larger peak flows reaching the pond and consequently require a bigger area. A typical retention pond will have at least 20 days retention time to permit biological degradation of pollutants. For industrial sites, a pond provides a final opportunity to catch oils and chemicals from accidental spillages around the estate.

Water features can be incorporated into both rural and urban settings to improve amenity value. Roof water from the site flows to this attractive water feature at the Wheatley Services Area on the M40.

## Wetlands

These are a further enhancement of retention ponds that incorporates shallow areas planted with marsh or wetland vegetation. They provide a much greater degree of filtering and removal of nutrients by algae and, to a lesser extent, by plants. Inlet and outlet sumps will improve performance and are recommended, since excessive sediment can quickly overwhelm the shallow area.

Only specially constructed wetlands should be used to treat surface water. It is not normally an acceptable practice to lead surface water into an existing natural wetland area.

Retention pond beside the A92, Dundee.

Constructed wetlands have proven to be effective in many developed countries, providing moderate to high levels of pollutant removal throughout the year. Constructed wetlands, designed by specialist consultants, will enhance their performance and longevity. A review of constructed wetlands was published by CIRIA in 1997 (*9*).

SUDS such as ponds and wetlands provide additional green areas and interesting water features within developed areas. They are useful for urban recreation and pollution tolerant wildlife. They can also provide corridors for wildlife to move between suitable habitats in urban areas.

# Conclusion

The traditional approach to draining developed areas is having a damaging impact on our environment and is not sustainable. Sustainable Drainage Systems offer a wide range of techniques which can be adopted for most new and redeveloped sites to give a reduced environmental impact from surface water drainage. To implement SUDS techniques effectively, developers need to consider their use at the earliest possible stage, as this may influence decisions on land purchase and the overall layout of the development.

They should consult with planning authorities, the Agencies and sewerage undertakers at the earliest stage of the development process. Widespread adoption of these techniques in new developments would see a long-term improvement in the quality of our urban rivers and a reduction in the risk of flooding. In addition, our urban environment would not only be more sustainable, but would also be more varied and attractive. Water features would be regarded as valuable assets instead of having water piped beneath the ground, out of sight.

# Glossary

**Adsorption** – The adherence of gas, vapour, or dissolved matter to the surface of solids.

**Aquifer** – A sub-surface zone or formation of rock or soil containing a body of groundwater.

**Attenuation** – The action of reducing a peak flow and increasing the duration of a flow event.

**Base flow** – The sustained flow in a channel or drainage system.

**Basin** - A ground depression that acts as a flow control or water treatment structure that is normally dry and has a proper outfall, but is designed to detain stormwater temporarily.

**Contaminated land** – Ground that contains substances which, when present in sufficient quantities or concentrations, are likely to have detrimental effects.

**Conveyance** – The movement of water from one location to another.

**Detention basin** – A vegetated depression that is normally dry except following storm events. Constructed to store water temporarily to attenuate flows. May allow infiltration of water to the ground.

**Diffuse pollution** – Pollution that comes from urban and rural land-use activities spread out across a catchment or sub-catchment. It is not from an industrial process or municipal sewage effluent.

**Filter drain** – A linear drain consisting of a trench filled with a permeable material, often with a perforated pipe in the base of the trench to assist drainage.

**First flush** – The initial runoff from a site or catchment following the start of a rainfall event. As runoff travels over a catchment it collects or dissolves pollutants. The 'first flush' portion of the flow may be the most contaminated as a result.

**Geotextile** – A plastic fabric that is permeable.

**Green roof** – A roof with plants growing on its surface. The vegetated surface provides a degree of retention, attenuation and treatment of rainwater. It promotes evaporation and transpiration, and contributes to local biodiversity. Sometimes referred to as an alternative roof.

**Greenfield runoff** – The surface water runoff regime from a site before development, or the existing site conditions for brownfield redevelopment sites.

**Groundwater** – Water contained in the soil or rock beneath the ground.

**Impermeable** – Will not allow water to pass through it.

**Infiltration** – The passage of surface water into the ground.

**Infiltration basin** – A dry basin designed to promote infiltration of surface water to the ground.

**Nutrient** – A substance (such as nitrogen or phosphorus) that provides nourishment for living organisms.

**Orifice plate** – Structure with a fixed aperture to control the flow of water.

**Passive treatment** – Natural processes used to remove and break down pollutants from surface water runoff.

**Permeable pavement** – A paved area that allows water to drain through the surface.

**Rainwater butt** – A small scale garden water storage device which collects rainwater from the roof via the drainpipe.

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

**SUDS** – Sustainable Drainage Systems: a sequence of management practices and control structures designed to drain surface water in a more sustainable fashion than some conventional techniques.

**Swale** – A shallow vegetated channel designed to conduct and retain water, but may also permit infiltration. The vegetation filters and retains solid particles.

**Transpiration** – The loss of water vapour through plant leaves.

**Wetland** – A flooded area where the water is shallow enough to enable the growth of bottom-rooted plants.

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Telephone: 08706 005522 to order

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ISBN 0 86017 485 9


References 3, 5, 7 and 9 are available from CIRIA, the Construction Industry Research and Information Association, Classic House, 174-180 Old Street, London EC1V 9BP
Tel. 020 7549 3300
www.ciria.org

**Further information and examples of sustainable urban drainage will be found in the following:**


- Urban drainage – the natural way. Hydro Research and Development, Clevedon, BS21 7RD, UK
Tel 01275 878371

- Scope for control of urban runoff. Report 124 CIRIA 1992. ISBN 0 86017 346 1


- on the internet; www.ciria.org/suds

- on SEPA's web site; www.sepa.org.uk

- on the Environment Agency's web site; www.environment-agency.gov.uk/suds

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