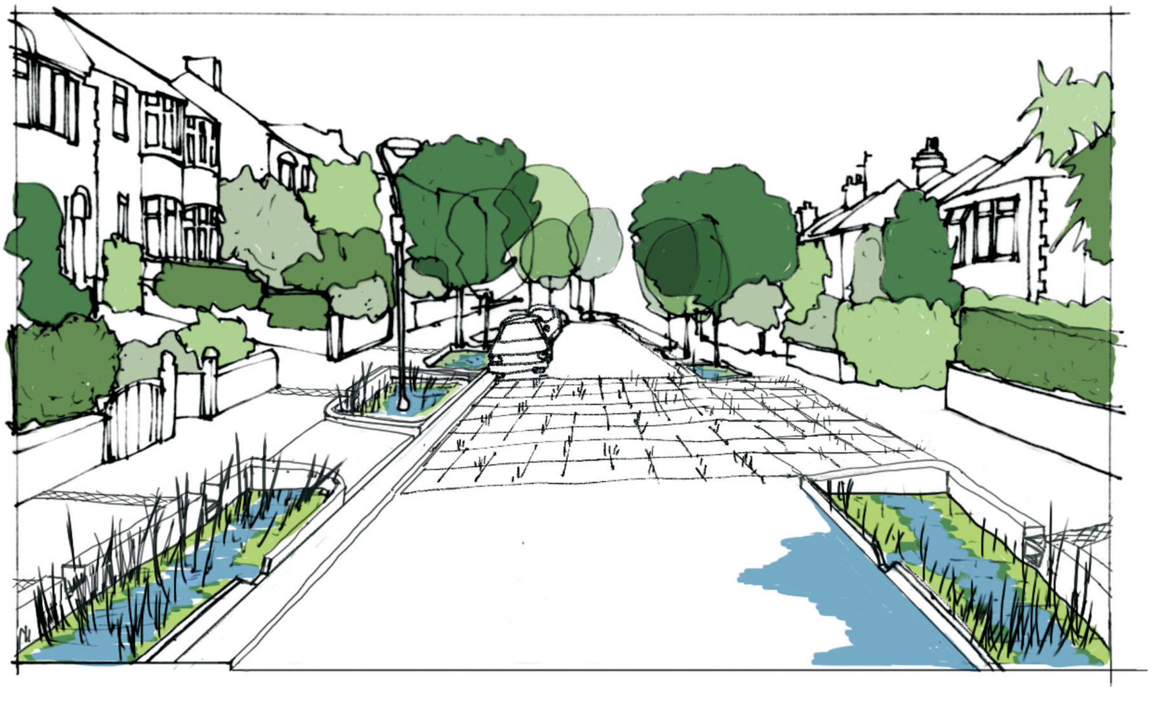
Retrofitting to manage surface water



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Retrofitting to manage surface water

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Executive summary

Over time, urban areas are enhanced through regeneration, maintenance and infrastructure improvements. There is a duty to manage flood risk and in response to the Water Framework Directive (WFD), reduce aquatic pollution. These will become even greater challenges in the future, with traditional solutions becoming more and more unaffordable. The task at hand should not be underestimated.

Retrofitting surface water management measures will deliver:

- drainage systems that mimic natural drainage processes
- management of pollution alongside flood risk
- the ability to adapt and manage extreme events
- extra benefits from better amenity, improved biodiversity, and greater resilience to climate change
- integration with urban design to create better places to live.

As urban areas are regenerated and the need to reduce flood risk and/or pollution has been recognised, there is an opportunity to manage surface water in a different way. The move away from a traditional approach of using a pipe based below ground system, to one that uses a wide range of above and below ground surface water management measures (SWMM) can be made. Taking this approach means that urban areas are enhanced to create better places to live. This will deliver a wider range of benefits than previously experienced.

No space is useless. Many opportunities to retrofit measures can be exploited if conventional thinking is challenged and an innovative approach to manage surface water is adapted. This can be done in both private land and the public realm. For example rain gardens (as seen in Islington) and tree pits can be retrofitted in the verge and pavement. Each space can be maximised so they have a dual function, such as play areas doubling up as a shallow detention basin (as seen in Malmö, Sweden). This will become easier if a range of professions work closely together to deliver joint solutions and a wide range of stakeholders are engaged early.

A retrofit rain garden on an Islington housing estate

Measures that mimic natural drainage processes can be introduced. This can help to improve the whole water cycle. Communities will benefit because the effects of a range of storms are managed. This is important particularly for rainfall that occurs every day. For more extreme events, measures that have the ability to adapt and have a dual function can be used. What is clear is that a range of measures need to be used.

A retrofit detention basin in a school in Malmö, Sweden, that also acts as a play and teaching area

As each urban community and setting is different, so the range of measures used will be different. Some measures will be installed where opportunities arise, as part of urban regeneration and driven by policy and regulations. Others will be delivered strategically, as part of a flood risk

What retrofit measures could look like:

- existing buildings will be fitted with green roofs and rainwater harvesting systems
- roads will have rain gardens in their verges, collecting and storing runoff, removing pollutants and calming traffic
- some roads, paths and spaces between buildings will be reshaped to carry surface water, and during extreme events act as "blue" flood pathways when the capacity of drainage is exceeded
- open areas such as parkland and car parks will be designed and designated to act as temporary flood storage
- at the same time they will provide green infrastructure benefits such as creating places for recreation and reducing urban heat islands
- surface water management will be an integral component of urban design, providing a host of benefits such as enhancing amenity, increasing biodiversity and enhancing land value
- local flood protection measures will be installed to make buildings more resistant to flooding.

management or pollution control programme. Whatever measures are used, they will be consistent with good urban design practice, creating a better place to live in.

These retrofit measures can work in tandem with existing systems, providing greater capacity for future challenges. With climate change, urban growth and infill development, retrofitting these measures will allow us to cope with these issues and manage the future risks better.

The guidance

This guidance provides a framework to help more effective retrofitting of surface water management measures. It outlines how to take a strategic or opportunistic retrofit approach depending upon the aims. It emphasises the importance of urban design when retrofitting. It outlines how to identify the opportunities and locations where it is possible to retrofit measures in a structured way, both at an optioneering level and then in more detail. It sets out how to overcome the common hurdles to retrofitting SWMM in the UK and guidance is given on how to assess the costs and full range of benefits that will often go beyond the initial aims of a scheme. Finally it considers important implementation and monitoring activities. It is applicable to a wide range of disciplines, professions and stakeholders, deliberately not targeted to one audience.

Scope of the guidance

The guidance is primarily intended for use by those working with the existing urban environment and who wish to manage surface water in a way that maximises the benefits and tackles the future challenges. It focuses on how to retrofit SWMM into the urban environment, either as part of a strategic programme of work or by realising opportunities incrementally as they arise.

Fundamental to the guidance is that it complements and should be read in conjunction with other guidance, and relevant national legislation and local policies. It provides an approach that can be used across the UK, applicable to the local situation and communities. It aims to inspire a new way of working and is relevant to a wide range of professionals and organisations including:

- spatial planners
- architects
- urban designers
- drainage engineers
- highway engineers
- land managers
- landscape architects
- local authorities
- sewerage undertakers
- environmental regulators
- developers.

Reference

CIRIA

Balmforth *et al* (2006) *Designing for exceedance in urban drainage systems*

Dale *et al* (2011) *Delivering biodiversity benefits through green infrastructure*

Dickie *et al* (2010) *Planning for SuDS – making it happen*

Woods-Ballard *et al* (2007) *The SuDS Manual*

Other guidance

Ashley *et al* (2011) *Surface water management and urban green infrastructure. Review of current knowledge*

Community Forests North West (2011) *Green infrastructure to combat climate change*

CNT (2010) *The value of green infrastructure. a guide to recognizing its economic, environmental and social benefits*

Croydon Council *et al* (2011) *Developing urban blue corridors*

Defra (2010) *Surface water management planning – technical guide*

English Partnerships (2007) *Urban design compendium*

What it contains

The guidance is split into three parts. Part A is an overview and can be read as a standalone document by a wide range of individuals who wish to understand the benefits of retrofitting SWMM, the opportunities available, the challenges that are faced and how they can be overcome.

Part A also serves as the introduction to the more technical Parts B and C. Part B contains the main guidance, with case studies in Part C. A breakdown of the guidance is as follows:

- Overview of retrofitting surface water management (Part A)
- Technical retrofitting guidance (Part B)
- A framework for retrofitting (Part B, Chapter 6)
- Urban retrofitting – thinking about urban design (Part B, Chapter 7)
- Identifying and assessing retrofit measures (Part B, Chapters 8–11)
- Common implementation issues and monitoring considerations (Part B, Chapters 12 and 13)
- Supporting case studies (Part C)
- Supporting tables (Appendix A1)
- Glossary, abbreviations and acronyms
- References.

Part A: Overview

In this part

1 Why retrofit surface water management measures?

Courtesy City of Bradford Metropolitan District Council

West Yorkshire, 2005

1.1 Why surface water should be managed

There are many reasons for managing surface water, including the need to reduce flooding and improve water quality. However, there are also current obligations to meet (eg a sewerage undertaker's programme to reduce flooding and achieve environmental compliance), as well as the challenges with tighter legislation such as the Water Framework Directive (Directive 2000/60/EC) and resulting River Basin Management Plans (RBMPs), population growth, water resources and the effects of climate change. Continuing the current approach to resolve these challenges (often through increasing the size of sewers or underground storage) is perpetuating unsustainable solutions that are not adaptable to a changing future (Ashley *et al*, 2007). There are many opportunities for taking a different approach to managing surface water that fits into the urban landscape better than before, while also addressing these issues (Box 1.1). These new approaches are known to be more adaptable and flexible, allowing future modification to cope with climate and other changes in urban areas.

Box 1.1 Retrofitting ponds in an urban area

- in Bradford, settlement ponds were retrofitted to improve the water quality in a stream
- the Bradford Metropolitan District Council Urban Design Team involved the local community to understand their views in the design as well as planting days.

Courtesy City of Bradford Metropolitan District Council

Retrofitting surface water management measures (SWMM) can help to solve some of the flooding and water quality problems that are faced today. Such measures provide a more joined-up approach to managing surface water across wider areas, supporting the water cycle as a whole, helping to "green" urban areas, and generating multiple benefits in-line with an ecosystems services approach.

SWMM can be cheaper than traditional solutions, and nearly always provide more benefits (Box 1.2). In particular, those that use GI, can improve the urban environment and air quality (Foster *et al*, 2011), enhance biodiversity and create a better urban space. Also, they can help manage surface water from everyday rainfall (typically causing pollution), design events (often leading to flooding from below ground systems) and extreme events (extensive flooding and damage, as shown in the Chapter 1 introduction image on page 3).

New development offers an important opportunity to manage surface water better than has been done traditionally. It requires early consideration of drainage and SWMM in the development planning process (Dickie *et al*, 2010). However, new development forms only a small part of the urban area. If improvements can also be delivered to existing developed areas, then the benefits will be much greater.

The focus of this guide is retrofitting SWMM to existing development as part of regeneration, or directly to the existing fabric (Box 1.3). Individually, the benefits arising from the opportunities to retrofit on a site by site basis may be small. However if this is achieved consistently every time an opportunity arises (such as in Melbourne, Australia with the 10 000 rain garden programme, see Chapter 4), the benefits will grow to have a real impact on drainage systems, reducing flood risk and improving water quality.

Information

The main benefits of appropriate retrofitting SWMM are:

- flooding – manages the rate and volume of surface water runoff so reducing flood risk
- water quality – SWMM can treat and improve the quality of water before it enters streams and rivers
- amenity and aesthetics – retrofitting can enhance and improve the urban space, contributing to place making
- biodiversity and ecology – soft or green SWMM can increase biodiversity and ecology and enhance the area creating new habitats
- climate change – SWMM are typically more adaptable and flexible than traditional solutions, particularly those above ground. They can also help to reduce the urban heat island effect.

Note that some of these measures will provide more benefits than others

Box 1.2 Cost benefits of retrofitting surface water management with green infrastructure, Philadelphia, USA (Stratus Consulting, 2009)

In Philadelphia an assessment of options to control combined sewer overflow (CSO) spills over the next 40 years demonstrate that the multiple benefits from green infrastructure (GI) range from $1.9bn to $4.5bn, depending on the extent of measures used (level of surface water retrofitting from 25 to 100 per cent).

The multiple benefits include (but are not limited to):

- air quality improvements
- reduced potable water use
- improved biodiversity
- public education and recreation
- reduced building energy use
- urban heat island mitigation
- increased property values
- avoided traditional infrastructure costs
- reduced flood risk
- improved water quality
- increased groundwater recharge
- reduced wastewater treatment
- CO_2 reductions.

Many examples from around the world show that reducing surface water entering a drainage system (through retrofitting) can be more cost effective than increasing drainage capacity (USEPA, 2007, and Gunderson *et al*, 2011). Also, there are many other benefits of using GI and SWMM together, providing better places to live and also helping urban areas cope with climate and other changes (Ashley *et al*, 2011).

Reference

Dickie *et al* (2010) *Planning for SuDS – making it happen*

Retrofitting can be used strategically (see Section 6.2) to tackle known drainage problems. This can be where surface water flooding occurs from various drainage systems. It can be where combined sewers are overflowing or where surface water sewers are discharging directly and polluting watercourses. Alternatively, if the sewer systems are at capacity, this can restrict further development.

Managing stormwater flows on the surface may be better than building large underground surface water systems alone, although it should be recognised that this is easier to do in some areas than others. Often a mix and match approach of measures will be critical to achieve success. It is important to plan strategically so as to know where to retrofit, what measures to use and when to do it. Linking this with future development and regeneration helps to deliver a holistic management approach. This will gradually deliver greener and more pleasant urban areas (CABE, 2010a).

Retrofitting needs close co-operation between the main stakeholders, most likely through developing strong partnerships or alliances (see Chapter 8) with and within organisations and across different disciplines. Widespread engagement with local communities will be vital to successful implementation.

Information

Categorising the types of rainfall and its typical effects (rainfall events are presented as a return period or as the probability that the event will occur within any given year):

- everyday events are typically up to a one in one year storm (100 per cent probability) that can cause water quality impacts due to their frequency of occurrence
- design events typically range from a one in two year (50 per cent probability) to either a 30 year (3.3 per cent probability) often for below ground systems or up to one in 100 year (one per cent probability) storm often for watercourses, and when fail lead to inundation
- extreme events are normally greater than a one in 30 year (<3.3 per cent probability) or one in 100 year (one per cent probability) storm and often lead to overland flow, extensive flooding and damage.

1.2 Realising the benefits of retrofitting

Unlike traditional drainage approaches, many SWMM manage runoff on the surface using multifunctional space. This means that they will be visible to the local community during both everyday and extreme events. Experience suggests people's expectations need to be understood and appropriately managed. Engaging with the community in the development of the most effective and acceptable SWMM is imperative. This helps to overcome perceptions of risk and concerns as to how to maintain these systems and, more importantly, explain their benefits and operation.

Usually the best results are achieved when SWMM are integrated into the design (or upgrading) of the urban fabric (see Chapter 7), for example as part of an area wide regeneration project. As well as managing flood risk, water quality can be improved and a better urban landscape created (CABE, 2010b). This helps to create better places to live (Box 1.4).

A feature of retrofitting "soft" SuDS specifically is the introduction of more vegetation and trees into the urban landscape. This is a component of GI. It helps to break down the harder appearance of constructed surfaces or unused green space and create a more pleasant vista. Trees and vegetation help to define the scale of a space, making large, unfriendly spaces smaller in parts, which are more conducive to a wider range of human activities.

Even retrofitting a small number of green measures can improve the biodiversity of an area through the creation of new habitats. Creating interconnecting green and blue corridors can also provide routes above ground for extreme or exceedance flows to pass through causing a minimum amount of damage (Balmforth *et al*, 2006, and Croydon Council *et al*, 2011). Planning for these should take account of the need to gradually develop these networks of interconnected corridors, with a strategic and long-term plan (see Chapters 9 and 10). The synergies between promoting biodiversity (part of Biodiversity Action Plans (BAPs)) and GI (part of Green Infrastructure Strategies) at the same time as extreme event flood control can be very cost effective, as has been found in East Riding, Yorkshire and is promoted in a Defra report (Croydon Council *et al*, 2011).

Box 1.3 An urban area retrofit to manage surface water, Bristol, UK

- an opportunity to regenerate an area of Bristol coincided with a lack of capacity in the local combined sewer
- following consultation with the local residents, a shared space "homezone" was created that removes traditional distinctions between pedestrian and car space
- surface water is now controlled using permeable paving, which reduces pollution in the local watercourse.

Courtesy Sustrans

Information

Typical surface water management measures (SWMM)

- SuDS components such as swales, basins, permeable surfaces, geocellular storage, water butts, rain gardens. Some SuDS components are also known as GI
- traditional drainage such as pipes and gullies where appropriate
- multifunctional assets for extreme events such as highways that can act as flood channels and play areas that can act as detention basins
- flood resistance and resilience measures for properties and assets.

Certain SWMM can help manage the runoff by local harvesting for direct use or temporary storage, infiltrating it into the ground, or attenuating it (slowing it down) close to its source. These are known as source control measures. These can be retrofitted to many property types as well as roads. However, the concept of managing stormwater on the surface not only applies at source. It also works well along the pathways that stormwater follows through the urban area. When stormwater is conveyed in pipes, the onset of flooding (when pipe capacity is exceeded) can be sudden, and impacts can rapidly overtake the implementation of an emergency response. Where surface channels are used (for example swales or rills), the transition to surface flooding is more progressive, allowing more time for response. Modern computer software can more accurately predict where floodwater will travel in extreme events, and this opens up

Box 1.4 Turning a high density residential street into one that can manage water above ground

- this terraced street has a high proportion of impermeable surfaces. During rainfall the runoff is rapid. The flow is not held back and surface pollutants are mobilised and carried into the combined sewer. Combined sewer overflows are needed to prevent sewers becoming overloaded
- in the proposed retrofit, roof water is delivered to planters. These retain some of the water and pollutants while improving the visual aspect of the street
- planters will retain a portion of the rainfall. Any excess is channelled across the surface to the road. Footpaths also drain to the road
- roads are drained by channels that discharge to bioretention areas. Here plants and trees absorb much of the runoff, and retain pollutants. These areas then drain to the existing sewer
- the visual impact and biodiversity of the street is improved, as is the quality of the water and air
- the bioretention areas also provide traffic calming and delineates parking bays.

the possibility of managing this flow. Creating surface flood pathways (for example by using roads as flood channels), and sacrificial flood areas (such as parks) can drastically reduce the effects of more severe floods.

Lastly surface water can be managed through retrofitting measures in the downstream areas that suffer the effect of urban floods or pollution (the receptors). Improving the fabric and design of buildings, can make them more resistant and resilient to floods. On a small scale, flood protection devices can be retrofitted to individual buildings. On a large scale, the space to create flood pathways and sacrificial flood storage areas can be created as part of regeneration projects. So urban planning and design has to be at the centre of retrofitting SWMM.

References

Balmforth *et al* (2006) *Designing for exceedance in urban drainage systems – good practice*

Croydon Council *et al* (2011) *Dealing with blue corridors*

Information

Green infrastructure (GI) and "soft" SuDS are more natural landscaped measures that manage surface water typically above ground in a more sustainable fashion than some traditional techniques. They often include trees and tree pits, swales, basins (dry, wet and infiltration), rain gardens, ponds.

They can create multiple benefits and are far more flexible and adaptable to climate change.

"Hard" SuDS are of an engineering nature and include geocellular storage, proprietary products, separators, hydraulic controls, kerbside drainage.

Information

The source-pathway-receptor concept for surface water management applies to all scales of retrofitting, either on a plot, neighbourhood or catchment scale:

- source is where the rain falls and where runoff is managed close to this point
- pathways convey flow, and can be on the surface or underground
- receptors are locations where an impact occurs, such as flooding or pollution. Receptors can also occur at source and along pathways.

These concepts were developed for systems where there are impacts from eg flooding or pollution. In SWM they apply to where there are opportunities and not just impacts.

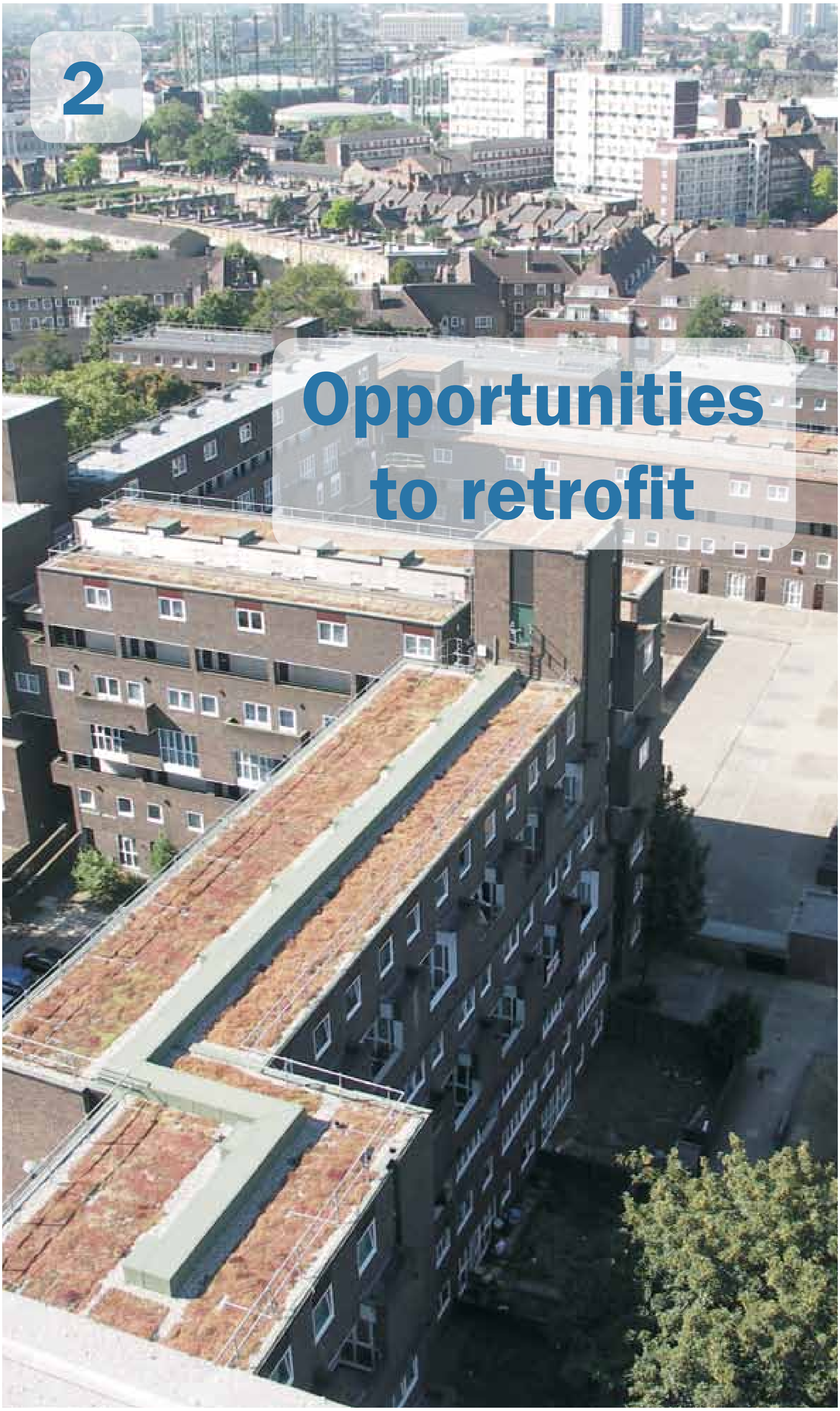
Summary

Why is there a need to retrofit SWMM?

- it is the only affordable, flexible and multi-beneficial option for long-term surface water management
- applying measures only in new development will not reduce the risk of flooding or improve water quality for a long time into the future that is needed in parts of the UK
- reducing surface water in sewers will reduce existing flood risk downstream
- reducing surface water in combined sewers will reduce combined sewer overflow discharges
- non-piped measures, particularly GI and soft SuDS components can be more readily adapted to cope with climate change
- to provide the stormwater capacity for new development
- source control can reduce pollution in surface runoff and the amount of water that enters watercourses
- infiltrating to the ground or using rain water harvesting can provide a valuable water resource
- retrofitting SWMM can increase amenity and biodiversity, making places better to live in
- the risk of flooding during extreme events can be managed using a wide range of measures
- the public will become better engaged with drainage and will take better care of their systems
- urban regeneration and the turnover of building stocks offer an opportunity to retrofit SWMM synergistically to provide adaptation to climate change at low cost.

Part A

2 Opportunities to retrofit



Courtesy Bauder

Retrofit green roofs, London

2.1 Enabling retrofitting

The different bodies responsible for the management and development of urban areas have traditionally worked in isolation, so often do not achieve all the benefits that might be possible with a more integrated approach. For example, it is not unusual to see major highway resurfacing projects aimed at creating a better urban space failing to achieve any benefits in managing urban flood risk (Box 2.1). UK legislation (eg Flood and Water Management Act 2010 and Flood Risk Management (Scotland) Act 2009) now require responsible bodies to co-operate and work more closely together to manage flood risk. Opportunities to create wider benefits from any retrofitting in urban areas should no longer be missed.

Box 2.1 Different approaches to replace a street parking surface in the UK

- both parking locations are in the same city and were recently changed
- (a) shows a permeable surface has been laid that allows grass to grow through and cars to park on the surface. This can allow the infiltration of water from the surface and the pavement above it
- (b) shows new tarmac to replace a mixture of hard standing and grass verge has been laid to enable parking. This means more water is discharged into the drainage system rather than infiltrating into the ground. This represents a missed opportunity for better surface water management.


a


b

Local planning policies can help surface water management (SWM) retrofitting. For example current and future surface water management plans (SWMPs) (Defra, 2010) or master plans provide the opportunity for a range of stakeholders to work together beyond their responsibilities to improve services and infrastructure with clear time lines and objectives. Understanding the benefits of retrofitting and where it can make a difference can influence and support GI strategies (UE Associates, 2010). Understanding the interactions and synergies between SWMPs, GI strategies and other relevant planning documents will be useful in fully exploiting benefits.

Retrofitting SWMM need to become part of the strategic plans of all relevant stakeholders, and these plans should fit together to make one coherent strategy. This will need more forward planning and greater sharing of information and aspirations than has been traditional practice. Many institutions are now recognising this need and actively promoting new partnerships to address the many challenges facing urban living (eg Planning and Climate Change Coalition, 2010, McCulloch and Robinson, 2011, and Croydon Council *et al*, 2011).

References

Croydon Council *et al* (2011) *Dealing with blue corridors*

Planning and Climate Change Coalition (2010) *Planning for climate change – guidance and model policies for local authorities*

2.2 Identifying retrofit opportunities

There are two main forms of retrofit opportunity (see Section 6.2). The first relates to urban regeneration or site reconstruction where the primary aim is not necessarily that of drainage improvement, but of site development, replacement or regeneration of building stock, enhanced urban environments and small local incremental improvements. Usually, but not always, these types of opportunity occur on relatively small areas or plots of land. They can include areas of improvement as part of green network strategies. This is referred to as opportunistic retrofitting or "nibbling".

The second opportunity will be drainage driven, either to control flooding or pollution (or both). Such opportunities usually (but not always) occur across comparatively larger areas and may be considered to be more strategic than the opportunistic retrofitting. Both types of opportunity may entail retrofitting across a whole area or a series of smaller "one off" retrofits.

Often opportunistic retrofitting of SWMM can be realised in addition to the primary reasons for redevelopment and other local area improvements. With strategic retrofitting aimed primarily at better SWM it may also be relatively easy to obtain wider regeneration benefits on the back of retrofitting SWMM.

2.3 Opportunistic retrofitting

When changes are made to the urban environment there is an opportunity to do a wide range of things differently. This may be when repairing, refurbishing or replacing part of an existing area (Box 2.2) or surface, or even reconstructing the grass and paved areas on a single plot. There may be no immediate reason for addressing surface water flooding or pollution, but simply an opportunity to modify a small part of the drainage system to manage water better. Here it is particularly important for responsible bodies, eg highway authorities, to understand and recognise opportunities that relate to their programme of works. In a time of economic constraint, getting more for less is an obligation that needs to be recognised by all the major players in urban development.

Information

Categorising the retrofit approach

- opportunistic retrofitting is where the chance to retrofit SWMM arises on the back of other drivers, such as regeneration or small scale improvements. These may occur within a neighbourhood, or locally on a plot level
- strategic retrofitting is where a SWM driver is present, ie to reduce flooding or improve the quality of a river. Here a wider approach across a neighbourhood or catchment may be taken to retrofit SWMM.

Box 2.2 Using new drainage to manage surface water in an urban regeneration project, Alkmaar, The Netherlands

- as part of an urban regeneration project, surface water is managed on the surface using source control (basins and wetlands)
- this helps to reduce the peak flow from the development as well as improving the water quality going into the watercourse
- this example shows how the measures have been designed to complement the architectural style of the buildings to provide a coherent and attractive urban landscape.

Courtesy M Leeuw

Where the introduction of physical measures helps another responsible body to meet their objectives, it may be that the cost of a scheme can be shared. This approach will most likely achieve other objectives, for example when retrofitting GI (eg by planting extra trees and greening streets) the opportunity to modify drainage systems to connect to the green areas, to keep them watered and also to absorb some of the runoff should not be overlooked. Such an approach can also improve the biodiversity of an area and support the aims of biodiversity action plans.

Through a wide range and number of small measures, opportunistic retrofitting can significantly reduce the overall runoff from a much wider area. This has been recognised in several cities in North America, including Toronto, Portland, Seattle and New York (eg USEPA, 2010). The benefit of doing this in terms of stormwater removal is illustrated in Box 2.3.

2.4 Strategic retrofitting

Resolving flooding and water quality problems by building different types of systems to those used in the past requires planning to work out what can be retrofitted where. This work will need to be done across the catchment and a systematic (strategic) approach to manage flooding or water quality should be adopted.

Box 2.3 The Toronto mandatory downspout disconnection programme

- in Toronto, Canada, a byelaw has been approved making it mandatory for property owners, city wide, to disconnect their roof downspouts from the sewer system
- the city suffers from major basement flooding and pollution, particularly of Lake Ontario. In 2005, a major investigation showed that disconnection would help prevent future basement flooding
- a programme, starting in 2011 and running to 2016, will disconnect some 250 000 properties
- the disconnection will divert water away from the property and, where necessary, include measures to prevent soil erosion.

Courtesy L Sharp

It is important to understand the underlying cause of the problem that is being dealt with (see Section 9.3) and the potential opportunity available. In urban areas the effects of flooding or water pollution are often remote from the source of the problem or where there are opportunities to create better urban spaces and manage the water differently. Urban drainage systems can also be complex. Computer modelling can help to build an understanding of the link between cause and effect, and this will then lead to robust solutions. However, climatic and other changes in the future may mean that the causes and effects of future challenges shift and now require opportunities to be seized that can be adapted in the future.

2.5 Identifying opportunities to retrofit SWMM

Broadly the types of opportunities can be put into three groups (see Section 9.7). Firstly, there are specific targets. These are areas where retrofitting now or in the future is easier to complete due to its current drainage or type of area. For example, an existing surface water sewer may drain to a combined sewer. The surface water could be diverted to a different outfall, so relieving the combined sewer of the flow (Box 2.4), or as in the examples in Boxes 2.2 and 2.3, stormwater may be removed at source from the piped drainage system. There may also be a large homogeneous area within the catchment that can be drained differently from now.

Box 2.4 Target opportunity to manage flows from a large car park area (pers. comm. V Goulding)

- in St Ives in Cornwall, UK a car park and green space of 2.5ha was known to contribute to downstream flooding. The car park and green space is shown in Figure 2.4
- the scheme was designed to a 100 year return period storm event and allowance for climate change. Measures included infiltration devices, an exceedance swale and underground geocellular storage.

Secondly there are common opportunities. This is where similar types of land use are identified and there is confidence that retrofitting similar types of measures can be done within them (Box 2.5). For example, a housing estate that is mainly semi-detached with wide roads and verges. This may allow retrofitting several similar measures across a whole estate.

Box 2.5 A common opportunity to remove flows from an existing system and improve water quality

- a housing estate with wide roads and verges has the space to build a variety of measures
- the grass verges can be used to convey flow through shallow swales or a mixture of permeable pavement and rainwater gardens. Due to spacious gardens, some form of downpipe disconnection or local storage could also be provided.

These opportunities will potentially take more effort to retrofit than the target opportunities, due to their size and complexity, but there are many of these types of areas across the UK. This can have a significant effect on managing surface water.

The final group of opportunities looks to the future. These are areas with the chance to retrofit when other work starts. This may be where there is an upgrade or renewal of highways or an area of regeneration (for non-SWM reasons) that enables surface water to be managed in a different and more sustainable way (Boxes 2.6 and 2.7). In this situation it may be possible to retrofit a wide range of SWMM (see Appendix A1) such as specifying the need for source control measures or allowing space to be created for surface flood pathways and sacrificial flood areas by changing previously developed space into green infrastructure.

If these various opportunities are taken advantage of, then gradually a change to how surface water is managed will take place, which will improve the look and feel of many urban areas. This will help to put SWM, with flood risk reduction, pollution control and the use of water for place making at the centre of urban design.

2.6 The role of traditional measures

This guidance focuses on how more innovative methods might be delivered (both above and below ground) of managing surface water in urban areas through retrofitting. However, there will be cases where more traditional drainage solutions will be appropriate, for example, increasing the capacity of piped infrastructure or adding new storage chambers or pumps. The measures set out in Chapter 1 and this chapter can be fully integrated with these traditional solutions in a "mix and match" way. This has been done in many of the cases already cited in North America where stormwater management at or near source has gone hand in hand with new in-sewer storage as hybrid systems. Stormwater removal has considerably reduced the size and cost of new sewer storage infrastructure while also providing extra benefits (Box 1.2).

Box 2.6 A future opportunity to remove flows and improve water quality in The Netherlands

- examples of urban regeneration programmes in The Netherlands where different types of measures have been built as an alternative form of drainage
- on the left, bioretention areas have been built that take runoff and help to improve the water quality before it is discharged locally
- on the right, flows are managed on the surface (similar to many Victorian terraced housing with channels under the footpath). The rain water from the roof comes down into a channel that directs the flow to the road. The road then carries the flow away using a shallow rectangular channel in the middle of the carriage way. The road has a reverse camber. There is no below ground surface water drainage.

Box 2.7 A future opportunity to remove flows and improve water quality in the US

- in Portland, Oregon, several streets have been through a transformation
- this has not only substantially reduced the amount of water going into the existing and purified any inputs, but also improved the urban space and calmed traffic
- the bioretention areas were retrofitted in 2003
- this was achieved by getting the residents involved in the design process. This included how much parking space to remove and what types of planting they prefer
- the residents have a shared responsibility to maintain the bioretention areas
- an information board (seen on the right of the image) provides local residents with useful and interesting facts about the bioretention areas.

Part A

2.7 Overcoming challenges

The perceived challenges of retrofitting SWMM often can be the biggest barrier to implementation. Section 9.6 discusses many of the practical issues to understand and overcome when retrofitting. Challenges that are often cited include land take, services location, ground conditions, topography, and the willingness of local communities to accept something different. To overcome this, it is vital to select the right measures for the urban context and available space. Chapters 7, 9, 10 and 12 provide further guidance on this.

Key challenges to overcome are:

- **land take:** this is perceived to be a challenge for not only retrofit SWMM, but also new build SuDS. The opportunity should be taken to develop multifunctional areas, such as green roofs on buildings, car parks with geocellular storage or play areas that act as detention basins (eg Mayor of London, 2011), to negate this challenge. Numerous measures outlined in Appendix A1 can be integrated to form a multifunctional solution. Innovative design, partnership working and early dialogue, particularly with the local community can help overcome this (eg Welsh Government, 2011)
- **services:** it is unlikely that services (gas, water, electricity) that are already present underground will be moved or changed. This is always expensive, so measures should be chosen to work within the constraints set by the location of underground services. It is also important that utility providers are involved early in the retrofit process to establish an effective working partnership
- **ground conditions:** every retrofit site will usually have different ground conditions. Understanding the ground conditions is no different to any drainage project. To overcome this, measures should be chosen to suit local site conditions. A "one size fits all" approach to individual opportunities is not applicable
- **topography:** understanding existing above ground flow paths is vital if water is to be managed on the surface. More accurate data sources for this are becoming more common, such as LiDAR, helping to identify flow pathways. Where it is not possible to manage flows above ground, a selection of traditional drainage measures may be necessary to convey surface water to an appropriate place to manage it further downstream
- **willingness of local communities:** the measures advocated in this guide often include surface features and their operation will not be familiar to the public. It is important to explain the benefits, discuss outcomes and adopt a programme of public engagement early in any project (see Section 8.4).

Section 9.6 outlines numerous other challenges that should be addressed before any surface retrofit takes place. This is similar to the typical approaches to retrofit traditional drainage although there can be more of these when using surface based systems. Ensuring that challenges are understood, planned for and overcome will be extremely important to the success of future retrofit projects.

Summary

Opportunities to retrofit

- retrofitting SWMM can be carried out on the back of other (non surface water) development and infrastructure projects
- the plans and policies of all stakeholders who work in the urban area should be specifically updated to include and offer direction to retrofitting SWMM
- retrofitting can come from the need to resolve a flooding or water quality issue, or general urban or environmental improvement
- opportunities to retrofit SWMM should not be missed. Look for "target", "common" and "future" opportunities
- retrofitting should explore both above and below ground measures
- retrofitting should address "every day, design and extreme rainfall events".

3

Why change?

Retrofit park in Seattle, Washington, USA

3.1 Key reasons for change

Modern cities need to be as attractive, effective and pleasant as possible and flexible enough to cope with an uncertain future. Recent initiatives are encouraging greater use of green and ecologically viable spaces alongside the traditional hard-paved developed areas (eg Planning and Climate Change Coalition, 2010, Dale *et al*, 2011, and HM Government, 2011). Such approaches can also help tackle the future need to adapt to rising temperatures and more extreme rainfall that will come due to climate change. Increasingly worldwide, urban surface water is being seen as a resource not a threat, with a wide range of benefits (eg Centre for Water Sensitive Cities, 2011).

Traditionally there has been the need for effective drainage to keep urban areas safe from flooding (Box 3.1). This is a continuing issue, and when drainage systems cannot cope, such as in the 2007 UK floods, property can be damaged, business and commerce disrupted and lives threatened. In 2007, 13 people died and the total economic cost of floods across England alone was £3.2bn (Environment Agency, 2010).

Box 3.1 Glasgow 2002 floods (courtesy Metropolitan Glasgow Strategic Drainage Partnership)

- in July 2002, exceptionally heavy rain over the city of Glasgow led to widespread flooding, with substantial damage to property and disruption to the local community. There was an outcry from local residents about why this had been allowed to happen
- although it was unclear who was responsible for the flooding, the sewerage undertaker and the city council came under significant pressure to ensure that measures were put in place to minimise the potential for future occurrences of such an event
- it was soon realised that both parties had responsibility for the flooding. They are now working together, and with others, in a strong partnership to reduce flood risk in Glasgow.

However, traditional drainage systems can lead to pollution of rivers and coastal areas, damaging the environment and ecosystems. Large sums of money are invested each year in maintaining and upgrading the UK's drainage infrastructure. In England and Wales sewerage undertakers plan to spend £3.7bn between 2010 and 2015 on improvements to meet flooding and water quality objectives (Ofwat, 2009). Traditional drainage is also a lost opportunity. If aspirations are to be delivered then the quality of urban areas should be improved in-line with those aspirations, especially greening where possible (eg HM Government, 2011, and Mayor of London, 2011). Rainfall and runoff needs to be seen as an opportunity. Green areas need to be irrigated and increasing green and blue infrastructure presupposes that water is kept on the surface as a resource and not passed directly to traditional infrastructure.

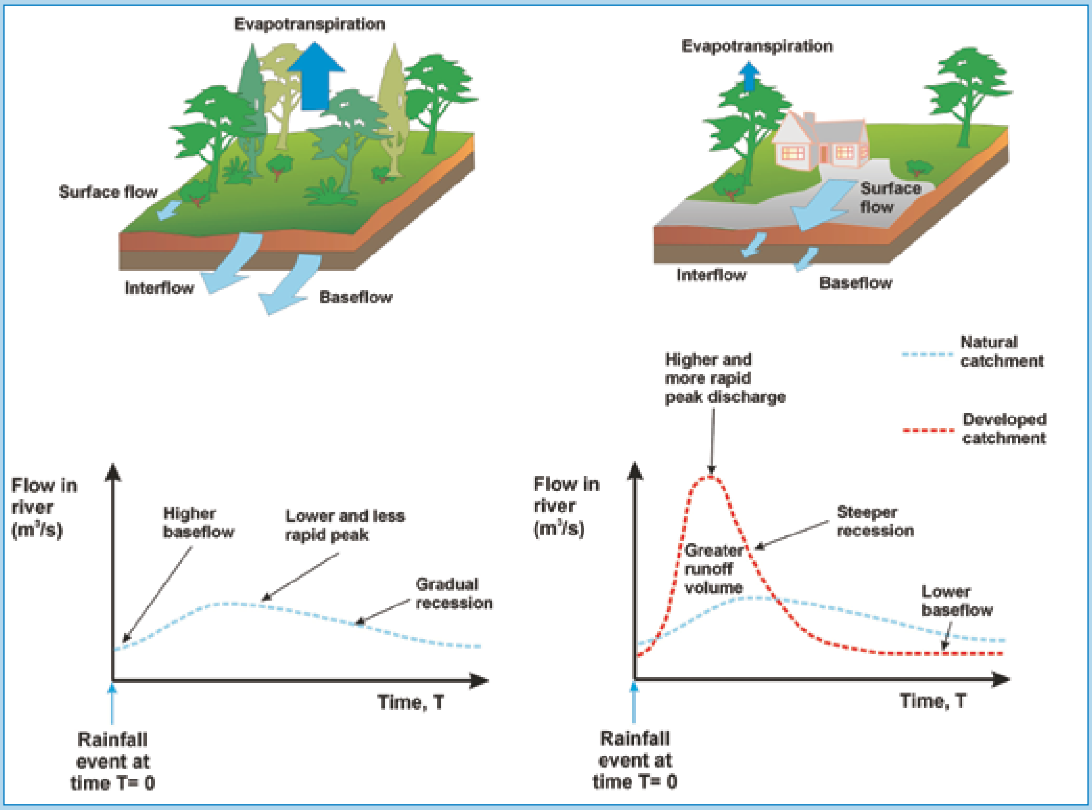
Climate change is predicted to result in at least a six fold increase in damage from urban flooding by 2080 if the current approach to flood risk management is maintained (Evans *et al*, 2008). In England and Wales, Ofwat (2008) is of the view that simply expanding the capacity of the sewer network to cope with this will be unaffordable. Urban creep, where grassed surfaces are paved will only add to the problem (Mott MacDonald, 2011). The EU Water Framework Directive (Directive 2000/60/EC) is placing further constraints on urban drainage systems in terms of their influence on the quality status of receiving waters and the engagement of communities in deciding how best to manage this.

Why has surface water become such a problem? To answer this it is important to understand how urbanisation affects natural drainage processes and why traditional methods of draining cities are no longer considered sustainable.

3.2 Historical development

Before human intervention, surface water drained via a system of watercourses and rivers to the sea (Box 3.2). In extreme rain events rivers naturally overflowed onto nearby land, creating a floodplain. Agricultural practices modified this to some extent, changing the runoff from natural areas as crops were cultivated, and altering drainage through the digging of ditches, which left the drainage system essentially intact. Urbanisation fundamentally altered the drainage process. Building over green space reduces infiltration into the ground, reduces evapotranspiration and accelerates the rate of runoff. This has the dual effect of increasing both the volume and rate of surface water runoff in urban areas.

Box 3.2 How changes in urbanisation affect the rate of surface water runoff



Originally channels, drains and sewers could accommodate the surface water runoff for all but the most extreme rain events, while the watercourses continued to drain the undeveloped areas that were left. But cities expanded rapidly, sewers quickly became overloaded and many watercourses were culverted to create even more space to build on. It was soon realised that investment in increasing sewerage capacity could not keep pace with urban growth. Sewer overflows were constructed to provide relief, but as many sewers also conveyed foul sewage, these overflows caused pollution to receiving waters (Butler and Davies, 2011).

Today the pressure on drainage infrastructure comes from three sources:

1 Urban areas are continuing to grow.

2 Within the urban areas, property owners continue to pave over natural ground, for example by paving front gardens to accommodate parked cars (UKWIR, 2009).

3 Climate change promises an increase in extreme rainfall events in most parts of the UK (Sanderson, 2010).

Increasing drainage capacity (sewers and watercourses) to cope with this is unaffordable and will also contribute to the factors that lead to climate change (Evans *et al*, 2004, and Ofwat, 2008). Ofwat (the regulator for English and Welsh water companies) recognises that building new or improved piped systems at this scale would lead to massive and unacceptable disruption in urban areas (Ofwat, 2008).

Piped drainage systems are less flexible and not easily adapted to future change and deprive communities of the multifunctional benefits that a mix of SWMM can achieve – water as a resource, pollution control, improvements in amenity and biodiversity. So doing things differently could offer benefits beyond the traditional flood control objectives and, at the same time, make urban areas better places to live in (Box 3.3).

Box 3.3 Lamb Drove SuDS showcase project, Cambourne, Cambridgeshire

- a SuDS scheme for a new local development includes green roofs, water butts, swales, detention areas, permeable surfaces and a retention pond
- the 35 dwelling development had already been designed using traditional concepts when an alternative SuDS based approach to managing surface water was introduced
- planned GI was modified for water management with open spaces becoming detention areas receiving water from permeable paved areas and roofs. Linear green areas were used for conveyance of both low flow and exceedance flow conditions
- as one of a few monitored SuDS schemes in the UK, it has shown that both flow rates, volume and water quality are effectively controlled by SuDS (Cambridgeshire County Council and Royal Haskoning, 2011)
- as well as SuDS, Lamb Drove also demonstrates some flood resistant and resilient design modifications.

Summary

Why change?

- existing approaches to managing urban drainage cannot cope with the future demands of climate change and urban growth. They will become unaffordable
- managing surface water using a range of measures offers more opportunities to use water at source and provides multifunctional, affordable and sustainable solutions
- new methods of SWM are more flexible and adaptable, and will be better able to respond to the uncertainties of the future
- new methods are also more effective at controlling pollutants in surface runoff
- new SWM methods exploit the benefits of more natural drainage systems to improve local amenity and biodiversity
- the more water surfaces in an urban area, the greater the cooling effect (Croydon Council *et al,* 2011). This will help tackle the effects of climate change.

4

How can change happen?

Courtesy G Fairhurst

Multifiunctional space in Malmö, Sweden

4.1 Design for multiple benefits

The measures set out in this guidance are already being delivered in many parts of the world. The drivers for this include a wish to clean up natural rivers and waterbodies, deal with increasing flood risk, use stormwater as a resource and adapt to future climate change. In many cases these measures are in response to growing urbanisation but also in recognition of the need to promote ecosystems even in urban areas (eg Watson and Albon, 2011).

Box 4.1 10 000 rain gardens, Melbourne, Australia

- the city council in Melbourne, Australia are responsible for drainage areas (up to 60ha) and are strongly committed to the principles of Water Sensitive Urban Design (WSUD) that seek to maximise the value of water
- across the city some 10 000 rain gardens are being retrofitted with the objective of improving the runoff water quality into Port Philip Bay at the same time as much of the city is becoming denser
- the gardens also take flows out of the stormwater system and create GI in the urban area and in many cases provide traffic calming. They are an effective, multi-beneficial initiative.

GI or soft SuDS components enhance amenity, ecological value and improve the quality of urban spaces. Even in densely urbanised areas, retrofitting GI is seen as desirable and effective (Ashley *et al*, 2011, Croydon Council *et al*, 2011, and Landscape Institute 2011). Highly developed urban areas are often considered to be too crowded to retrofit any measure that requires land. However, considering land use as multifunctional has been shown to be an effective way of dealing with this (Box 4.1). This means designing urban surfaces with overlapping uses, eg play areas and car parks used as infiltration surfaces, roads used as flood channels, parks used as temporary flood storage areas. With shared use, several different functions can be delivered where space is limited.

4.2 Combining drivers and timing the implementation

In the UK there are many different organisations responsible for land drainage, property drainage, SWM, highway drainage and rivers. Each has their own drivers, standards and budgets. The responsibilities of each separate body are tightly defined. This means an integrated approach to retrofitting SWMM may seem to be difficult to achieve, requiring close co-operation. However, there are good examples of retrofitting in countries with similar split responsibilities to the UK (Balmforth, 2011), demonstrating that with effective co-operation, new methods can be successfully adopted.

To make the most of the opportunities afforded by SWMM there is a need to develop solutions jointly, working through partnerships and alliances, sharing data, information, knowledge and resources. The surface water management plan technical guidance in England and Wales recognises this (Defra, 2010).

References

Defra (2010) *Surface water management plan – technical guidance, second edition*

Balmforth (2011) *Comparing the arrangements for the management of surface water in england and wales to arrangements in other countries*

Garrison and Hobbs (2011) *Rooftops to rivers II: Green strategies for controlling stormwater and combined sewer overflows*

Legislation in the UK suggests that various bodies have to work more closely together. To start with, this means greater sharing of information. This first step will help to develop relationships and build trust. For example, partnerships are bringing together all the local partners, such as the Cambridge Flood Risk Management Partnership and the Yorkshire and Humber Learning and Action Alliance. Working together will not only achieve better solutions, it will enable stakeholders to deliver their responsibilities more cost effectively and deliver greater overall benefits to society. Highway authorities, in particular, have a major role to play in facilitating retrofitting, as they are responsible for large surface areas in the public domain that generate runoff and pollutants.

In some dense urban areas, it may not be possible to fit the whole range of potential SWMM. This can particularly be the case where there are services that restrict the space to build or infiltration systems are too close to buildings or trees need to be preserved (Armour *et al*, 2012). In some cases a mix and match approach of traditional methods (eg underground storage) and newer methods can be combined to deliver a more limited range of benefits, or innovative options selected such as large planters near to buildings to maximise evapotranspiration and slow flows down (Box 4.2).

Box 4.2 Retrofitting into a shared space in Blackpool

- in Blackpool, a major highway improvement scheme has helped to improve the surrounding area. This included upgrading highways, remodelling existing car parks, landscaping, improving traffic and pedestrian management and constructing a new external plaza near Blackpool Football Club
- as part of the remodelling, SuDS were incorporated into the design. This included using stored rainwater to irrigate trees planted as part of the scheme
- the system comprises of a kerb system to collect and treat the storm flows from the highway. The treated surface runoff feeds into storage conduits fitted with filters. The stored water is then fed to rings of high strength modular crates filled with a hydrophilic material that absorbs water and releases it on demand. These are connected to the textile lined tree pits that irrigate the trees lining the new highway.

Courtesy Gillespies LLP

It may not be practical to achieve all the desired benefits at the start. In many cases a longer term plan will be needed. Here measures that can be more easily implemented can start first. Then as more opportunities arise, for example through redevelopment, further measures can be added. This is why an integrated and long-term plan is important. Long-term needs should not get in the way of delivering short-term benefits. This is particularly true where funding may only be available for a limited period. In the future, further incremental changes can be brought in using funding from other sources, possibly to deliver on requirements other than SWM.

4.3 Use a wide range of SWMM

Some may consider retrofitting SWMM using techniques other than pipes as an innovative and unproven approach despite the evidence from other countries (eg DTi, 2006, Weinstein *et al*, 2006, Schueler, 2007, Balmforth, 2011, and Garrison and Hobbs, 2011). The need to deliver certain outcomes within limited timeframes can be a considerable barrier to change in these practices. An effective way to deal with this is through pilot projects. A pilot project can be used as a "proof of concept". Deadlines and deliverables should be more flexible with pilot projects. Once a pilot project has been successfully delivered, other projects will follow more easily.

Information

- a wide range of measures can be used to manage surface water
- it is likely that in many cases hard and soft SuDS may be used in conjunction with more conventional measures
- this will include using multi use assets (where their primary function is not to manage surface water) to manage extreme events.

A common mistake when managing surface water is that only the more obvious flood risks are dealt with. A feature of the 2007 UK floods was that many areas that flooded had not been flooded before. Typically there is limited information regarding flooding from extreme events. The challenges of managing surface water in extreme events should not be underestimated. In extreme events, measures that manage flood water along pathways (where the water flows) and at receptors (where the water flows to) become more important. All SWMPs need to include an assessment of extreme events and develop measures accordingly.

Reference

Baca Architects and Scott Wilson (2010) *Toolkit on blue infrastructure: designing for climate change and flood-risk environments in Hackbridge – Part 1*

A Defra/EA report dealing with blue corridors (Croydon Council *et al*, 2011) outlines the approach needed and encourages the use of GI as well as recommending how minor changes to planning policy in England and Wales are required for this to work effectively. Separately, Baca Architects and Scott Wilson (2010) have developed a toolkit on designing blue corridors. In each case the blue corridors are a combination of providing blue spaces (water) during dry weather (day-to-day) periods for amenity and other uses, providing routes for the water during floods and additional routes during extreme floods. The approach has been applied in the Wandle Valley Park in London.

In many countries with existing drainage systems, such as the USA, Australia and Scotland, it is pollution rather than flood risk management that is the reason for retrofitting and managing surface water differently. As well as flood risk and pollution control, additional benefits from amenity, biodiversity and improved public space then follow, and are important in engaging the public. From the start, multiple benefits should be delivered on all schemes, irrespective of the primary objective (Grant, 2010 and Landscape Institute, 2011). Where possible, seek to maximise the opportunities for joint funding (Defra, 2011b) and look for imaginative, alternative sources of funding, such as GI strategies and highway maintenance and renewal budgets.

4.4 Working and engaging with partners and stakeholders

Stakeholder collaboration for small schemes, while important, can at times be managed informally, although do not underestimate the level of effort necessary. However, in large and more complex areas, more formal arrangements will be needed. For example, the challenge of regenerating the City of Glasgow has done much to encourage joint working between stakeholders, and has led to the formation of the Metropolitan Glasgow Strategic Drainage Partnership. This started with an agreement between two of the leading stakeholders and then grew progressively to include all stakeholders in a management group. Community involvement followed later. New arrangements usually start with one stakeholder acting as a champion and bringing other stakeholders on board because of the effort that is needed to gain agreement between stakeholders (Box 4.3). Often the public can be excluded from the early steps. Experience shows that some communities may be resistant to change and suspicious of new approaches. This can change through early engagement and discussing the problems and what is important to them, before any discussion takes place on a solution.

Since the success of many SWMM depends on public acceptance, a change in how the public are engaged is needed. There needs to be a move away from a “telling culture” to a “partnering culture” where the public feel that they have a genuine part to play in forming the future of managing surface water in their communities (eg Environment Agency, 2007 and Welsh Government, 2011). Where possible, use existing routes of communication with the local public when starting the process. However, be aware that the public often have an uninformed view of who is responsible for water and drainage systems and their role in the process. As a consequence, significant information will need to be provided for any meaningful engagement to take place and the process may be lengthy.

Box 4.3 Green Space Wales

Courtesy Dŵr Cymru Welsh Water

- in Wales, since 2007, Dŵr Cymru Welsh Water (DCWW) has been developing a surface water management strategy (SWMS) to reduce surface water entering the combined and foul sewers to achieve a wide range of benefits. This has been part of the Green Space Wales initiative
- the initial phases had a focus of raising awareness. It involved stakeholders and the public with the causes and consequences of surface water runoff and explained how people can take preventative action (DCWW, 2009)
- investigations have taken place to set the foundations for delivering a more sustainable approach to managing surface water, preferably on the surface
- in 2011 the SWMS started its next phase, focusing on more practical delivery and implementation using pilot projects, with agreed funding from Ofwat.

Summary

How can change happen?

- everyone involved with SWM needs to realise that the traditional ways of managing runoff are no longer going to be able to cope with the challenges in the future
- experience in other countries shows that the retrofitting of SWMM is feasible in even the most highly developed and densest urban communities
- using urban space for more than one function can provide a route for finding the space and funding to incorporate SWMM that include surface features
- pilot projects are a good way to establish and demonstrate the value of innovative approaches, especially with those who are more sceptical
- there are many examples of successful projects and these should be referred to when promoting SWMM
- partnership working is important. In all but the simplest of schemes, formal arrangements will be needed
- do not let the time frame and complexity of larger schemes get in the way of short-term benefits. This is particularly important where initial funding is limited
- equally, do not refrain from making small improvements now where the benefits are not likely to be significant for some time in the future
- good public engagement is not the same as good public communication. To be effective, it requires a commitment to build the capacity for the public to meaningfully participate in deciding how best to manage surface water.

5 What measures to use?

Courtesy R Newton

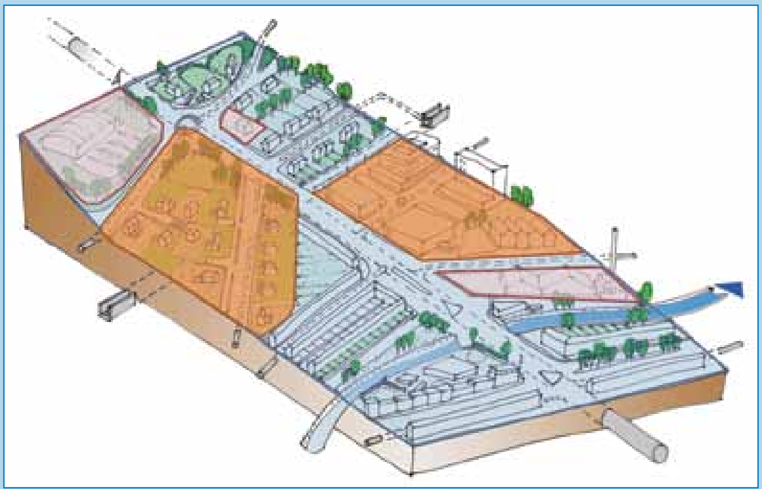
Rain garden retrofit, Islington, London

5.1 Scales of retrofitting

To understand the types of measures to use, it is important to understand the size of the retrofit. This can cross a range of spatial scales (Box 5.1) from a single plot, to a neighbourhood or a catchment. These are deliberately flexible. Any of the scales apply to a strategic or opportunistic retrofitting approach (see Chapter 2).

Box 5.1 Different spatial scales of retrofitting

- plot level: this may be the individual disconnection of a residential roof or part of a larger commercial building. Plots apply to both private and public land
- neighbourhood level: retrofitting applies to a number of plots, often across a number of streets. Measures may join up, to link flow from one to the next
- catchment level: a number of neighbourhoods will join together



Many local conditions, including the urban context and the existing opportunity to retrofit will dictate the types of measures that are feasible. However the driver, and the types of rainfall events to manage, are important. This guidance focuses on managing three types of events. Everyday rainfall, typically impacting on water quality, design events that typically cause flooding in urban areas and extreme events when inundation of urban areas could take place.

By understanding the size, context and driver, it is possible to identify the opportunities to retrofit measures at source, along pathways and at receptors. These apply to all scales.

5.2 Implementing measures close to the source

As a first step to determining what opportunities there may be, look at some of the more innovative approaches being adopted in other countries around the world. There are measures that use, retain, hold back and store surface runoff at source (close to where the rain falls). These use, for example, green roofs, infiltration or local storage with rainwater barrels or cisterns and water storage in tanks to flush toilets (eg da Silva, 2011). This is known as source control.

Source control aims to maintain or return the drainage of local areas to a state that is closer to natural drainage processes (Boxes 5.2 and 5.3). If used collectively in several properties, source control measures can reduce water demands and significantly reduce the volume or rate of runoff that downstream systems have to cope with and under many circumstances also reduce the carbon footprint. Also, it can help to reduce pollution, and where green roofs are used, improve amenity and biodiversity and add other benefits to building energy needs (Castleton *et al*, 2010). Smaller storage systems can provide opportunities for irrigation of gardens and also for urban horticulture (eg CABE, 2009).

Box 5.2 Managing flows at source through downpipe disconnection, Portland, Oregon, USA

- since 1995 a "downspout disconnection programme" has given homeowners and other stakeholders the chance to work as partners with the City's environmental services department to reduce sewer overflow discharges
- homeowners are given financial incentives to disconnect and many are proud to display notices in their gardens saying they have disconnected
- this has seen over 56 000 downspouts being disconnected from the sewer system as an alternative way to manage rainwater from roofs
- this removes more than 250 000 m^3 of storm water per year from the sewers.

Box 5.3 Managing flows at source through rain gardens, Portland, Oregon, USA

- built in 2005, this street retrofit of a rain garden on SW 12th Avenue Green Street receives surface water runoff from the highway
- for many every day events, these prevent flows entering the sewer, effectively disconnecting the contributing area
- four of these are planted in a row that take flow in series. Only during extreme events do flows enter the sewer
- nearly all of the streets annual runoff enters the rain gardens

5.3 Implementing pathway measures

The concept of mimicking natural processes can also be used to look at how surface water is conveyed through urban areas. Exploiting the drainage pathways is another area for retrofitting measures. Although GI is preferred, it does not rule out hard engineering techniques such as kerb drainage.

Green surface pathways provide the important corridors linking GI features together. This is important for effective ecological systems, which require continuous pathways for wildlife to move through (Benedict and McMahon, 2006). These green corridors can also become blue corridors during periods of excessive rainfall (Croydon Council *et al*, 2011).

In contrast, traditional piped drainage systems are expensive to provide and have limited capacity. They convey flow rapidly, so are effective at draining local areas, but the rate at which flow is transferred can increase flood and pollution risks downstream. Storage can reduce this effect, and the construction of underground storage tanks has been used as a means of improving drainage systems in recent history. However, this is very expensive, and once the capacity of below ground systems is exceeded, flooding occurs suddenly.

Surface channels can avoid these drawbacks. When designed to mimic natural processes, flow is attenuated, peak flows reduced, and water quality improved. These can be built from natural materials (eg grassed swales) or using hard surfaces and can provide attractive water features in the urban landscape once it begins to rain (see Chapter 4 cover image). These also avoid the problems of a sudden onset of flooding and can be extended to manage the safe conveyance of surface flows when drainage capacity is exceeded (Boxes 5.4 and 5.5).

5.4 Retrofitting of receptors

There are many opportunities to retrofit at receptors (ie locations where water may be conveyed to). Even with measures at the source, or along pathways, there may still be water conveyed downstream. This water can be useful and collected as a resource (see Section 5.2). It can provide wildlife areas in ponds or wetlands, and also as areas for recreational use. Measures can be "taken off-line" and used for aesthetic and visual attractions. There may also be a residual risk of flooding along the pathways and in downstream areas, or a water quality issue due to contaminants picked up from roads or other surfaces. The parts of urban areas that are affected by flooding or pollution are often known as the receptors (Evans *et al*, 2004). Understanding the risks to receptors helps in planning suitable mitigation measures where taking opportunities had not managed these risks to an acceptable degree. Conventional building design does little to make the building fabric resistant or resilient to flooding. Also, traditional building materials are easily damaged by flood water so it can take a long time and be expensive to renovate buildings after a flood occurs.

Box 5.4 Conveying surface water on the surface, The Netherlands

- rainwater from property discharges onto a non-strategic road. It is conveyed in a channel in the middle of the road
- in extreme events the road fills up so the whole carriageway acts as a conveyance channel
- people are far more familiar with surface water being on the surface.

Courtesy E Jannsen

Box 5.5 Overland flow in the urban area, Glasgow, Scotland

- in 2002 a major rainfall event resulted in exceedance from the drainage systems in the urban area
- although the highways were not necessarily designed to convey exceedance flows, they formed major conveyance routes, with surface water running overland
- they were not designed to function as conveyance routes so there was no control of the surface water, and widespread flooding occurred.

Often, there will be opportunities to provide localised protection to receptors (Box 5.6) that are cost effective and realistic. A range of measures are now available that can be retrofitted to buildings and other infrastructure to reduce the probability of negative effects from flooding. Local measures can also be applied to receiving water, or the outlets from the drainage system into these where, for example, the debris and silt carried in the flows can be trapped to reduce the effect of polluting discharges.

Rarely will a single SWMM be sufficient to effectively manage even residual flood risk at a receptor. A range of measures used together usually prove to be cost effective and provide a wider range of benefits as outlined previously and in Chapters 1 and 2. Measures may be considered at source, pathway and receptor, and for the different types of events (see Chapter 1) to combat flooding and improve water quality. Retrofitting these types of measures into a catchment, neighbourhood and plot perspective will make use of the opportunities available. Figure 5.1 (see page 30) gives an example of just some of the measures that may be possible in different types of urban areas to manage the surface water differently. This uses measures that manage flows close to their source, along pathways and at receptors.

Part A

5.5 Using different types of SWMM together

Given the range of measures that are available to retrofit (see Appendix A1), it is important to use a selection that makes the most of the opportunities for each application. It is appropriate and right to mix and match the types of measures. The types of opportunity (see Section 9.7), the context of the retrofit (see Chapter 7) and the practical retrofitting issues (see Section 9.6) will often dictate the mix. For example, it may be necessary to use pipes when the local topography does not allow for the water to be managed on the surface or to connect the surface measures together.

The types of measures include both hard SuDS components (such as geocellular storage, flow control devices and proprietary treatment devices) and soft landscaped SuDS components (such as rain gardens, swales, bioretention areas and basins). Also, more traditional measures will be appropriate as part of an integrated solution along with using "multifunctional" assets.

The successful integration of such measures will use the opportunities that are appropriate to the context of the retrofit (see Chapter 7), are affordable, and generate the maximum multiple benefits possible. This will help to overcome reluctance and potential barriers to retrofitting such as a perceived lack of space, infiltration capacity or health and safety risk.

The integration of the various types of SWMM has been shown on several projects, both overseas and in the UK (Boxes 1.3 and 4.2), and can be adapted to manage surface water at opportunities found in the catchment, neighbourhood or plot scale as appropriate, using measures that fall under the source-pathway-receptor categories.

Box 5.6 *In situ* flood defence to protect property from flooding, Sheffield, UK

- property flood protection measures provide a valuable way of preventing local flooding
- these can be designed to fit within the urban space during everyday use and only operate when there is a risk of flooding.

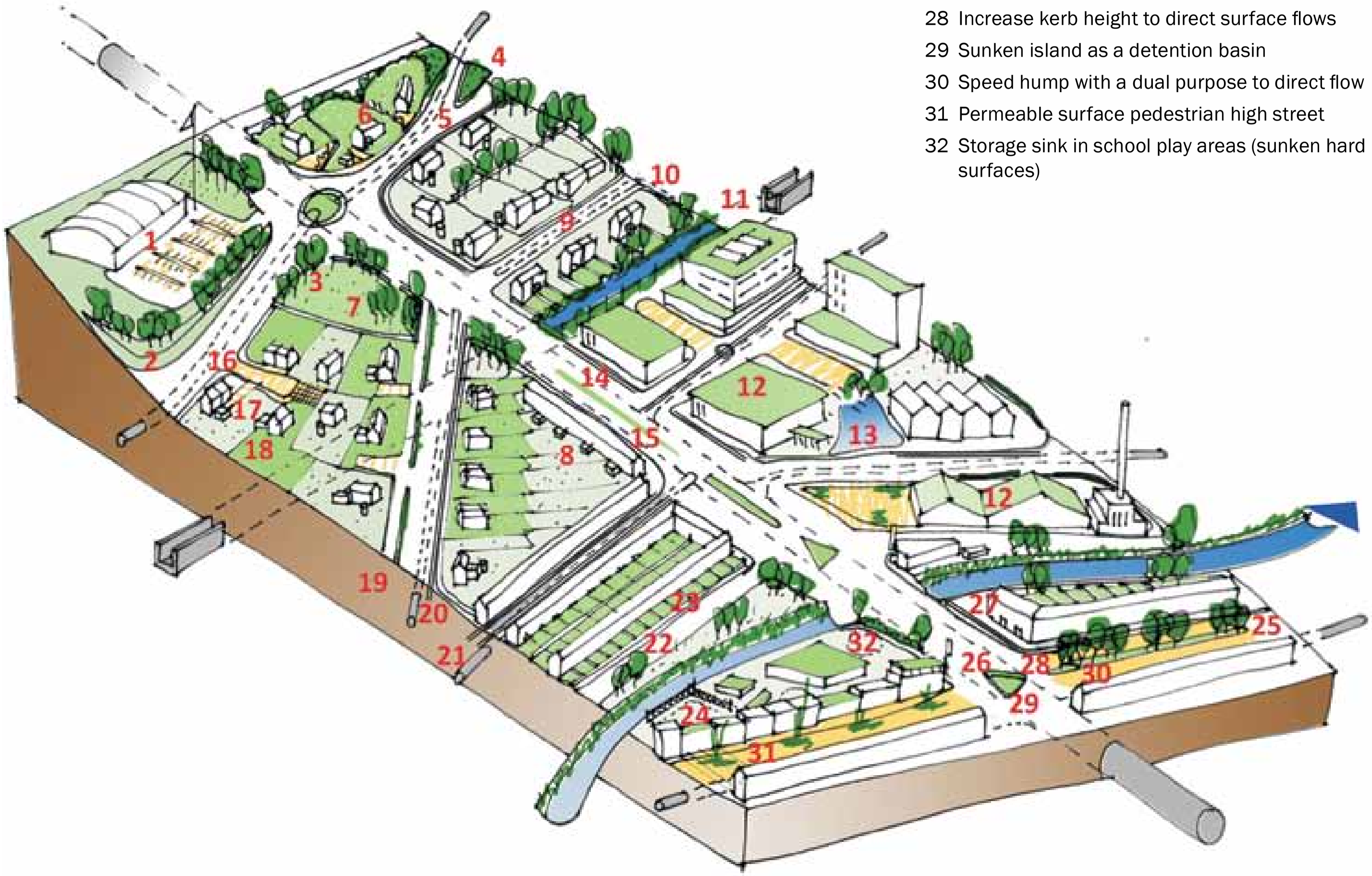
Courtesy Tilt Dam

Summary

What measures to use?

- keep surface water on the surface where practicable
- keep surface water separate from foul sewerage
- use drainage systems that mimic natural processes to manage flood risk and manage water quality, such as SuDS
- increase the amount of blue and green infrastructure
- plan how best to manage surface water in urban areas using three levels: everyday events, events that the drainage system is designed to cope with and any more extreme events, ensuring that in each case maximum benefits can be achieved
- use measures that can aid mitigation and adaptation to climate change
- where possible make space for flood water during extreme events using blue corridors
- reduce the vulnerability of receptors by protecting them through resistance and resilience measures
- maximise the potential for urban liveability, biodiversity and amenity improvement
- integrate surface water into urban design for multifunctional use.

1 Permeable paving, biofiltration (rain gardens) and geocellular storage
2 Filter strip with vegetation leading to swale
3 Biofiltration swale
4 Biofiltration area in public open space
5 Street planters
6 Water butts draining to private rain gardens with complete downspout disconnection
7 Shallow detention basin in public open space, dual use as a playing area
8 Water butts at rear of properties (with excess back to sewer), water from roofs at front drain to highway
9 Kerbside shallow channels, with street planters
10 Swale conveying surface flows to watercourse
11 Watercourse daylighting (underground culvert opened up)
12 Green roof retrofit and rain water harvesting
13 Detention basin with connecting swales and above ground channels taking flows from local area
14 Kerb drainage
15 Swale
16 Permeable pavement
17 Permeable surface driveway
18 Water butts draining to private rain garden (front and rear)
19 Verge converted to a swale
20 Kerb side shallow channel with street planters
21 Kerb side shallow channel
22 Biofiltration swale in public open space
23 Front garden with retrofit planters and water storage underneath.



24 Detention basin with connecting swales in public open space
25 Planters retrofitted in series including trees within the pedestrian area
26 Re-profiled road to divert flow downstream
27 Water tight doors and air brick covers
28 Increase kerb height to direct surface flows
29 Sunken island as a detention basin
30 Speed hump with a dual purpose to direct flow
31 Permeable surface pedestrian high street
32 Storage sink in school play areas (sunken hard surfaces)

Figure 5.1 *Catchment view illustrating various SWMM that can be retrofitted across different land use types*

Glossary, abbreviations and acronyms

Glossary

Amenity	The quality of a place being pleasant or attractive, ie its agreeableness. A feature that increases attractiveness or value, especially of a piece of real estate or a geographic location.
Appraisal period	The agreed time over which the costs and benefits are assessed and then discounted.
Attenuation	Reduction of peak flow and increased duration of a flow event.
Basin	A ground depression acting as a flow control or water treatment structure that is normally dry and has a proper outfall, but is designed to detain stormwater temporarily.
Benefit cost ratio (BCR)	The net present value divided by the costs (normally the capital and operational costs).
Blue corridor	A planned pathway that contains surface water in the urban area such as watercourses, overland flow paths, surface water ponding areas. These join up to create a network of corridors. Also can be referred to as "blue infrastructure".
Biodiversity	The diversity of plant and animal life in a particular habitat.
Bioretention area	A depressed landscaping area that is allowed to collect runoff so it percolates through the soil below the area into an underdrain, promoting pollutant removal.
Brownfield site	A site that has been previously developed.
Catchment	The area contributing surface water flow to a point on a drainage or river system. Can be divided into sub-catchments.
Combined sewer	A sewer designed to carry foul sewage and surface runoff in the same pipe.
Contaminated ground	Ground that has the presence of such substances that, when present in sufficient quantities or concentrations, are likely to have detrimental effects on potential targets.
Conventional drainage	The traditional method of draining surface water using subsurface pipes and storage tanks.
Conveyance	Movement of water from one location to another.
Curtilage	An area of land around a building or group of buildings that is for the private use of the occupants of the buildings.
Design codes	These are defined as detailed design guidance, which is stricter and more exact than other guidance.
Design criteria	A set of standards agreed by the developer, planners, and regulators that the proposed system should satisfy.
Designing for exceedance	An approach that aims to manage exceedance flows during rainfall events, eg the use of car parks during extreme events.
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.

Detention pond/tank	A pond or tank that has a lower outflow than inflow. Often used to prevent flooding.
Diffuse pollution	Pollution arising from land use activities (urban and rural) that are dispersed across a catchment, or sub-catchment, and do not arise as a process effluent, municipal sewage effluent, or an effluent discharge from farm buildings.
Discounting	A method to compare the benefits and costs that arise over the appraisal period. The discount rate converts all costs and benefits to the present day to determine the present value (PV) or whole life cost (WLC) so they can be evaluated consistently.
Ecology	All living things, such as trees, flowering plants, insects, birds and mammals, and the habitats where they live.
Ecosystem	A biological community and its physical environment.
Ecosystem services	The multitude of resources and processes that are supplied by natural ecosystems.
Environment	Both the natural environment (air, land, water resources, plant and animal life) and the habitats where they live.
Environmental regulators	These include the Environment Agency (in England and Wales), the Scottish Environment Protection Agency in Scotland and the Northern Ireland Environment Agency.
Erosion	The group of natural processes, including weathering, dissolution, abrasion, corrosion, and transportation, by which material is worn away from the earth's surface.
Evapotranspiration	The process by which the Earth's surface or soil loses moisture by evaporation of water and by uptake and then transpiration from plants.
Everyday events	Events with a return period of less than one year (100 per cent chance of occurring in any one year). These events typically cause pollution.
Extreme events	Events of greater than 30 year return period (3.3 per cent chance of occurring in any one year). Can often lead to major flooding with substantial damage.
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.
Filter strip	A vegetated area of gently sloping ground designed to drain water evenly off impermeable areas and to filter out silt and other particulates.
Filtration	The act of removing sediment or other particles from a fluid by passing it through a filter.
Flood routing	Design and consideration of above ground areas that act as pathways permitting water to run safely over land to minimise the adverse effect of flooding. This is required when the design capacity of the drainage system has been exceeded.
Flora	The plants found in a particular physical environment.
Forebay	A small basin or pond upstream of the main drainage component with the function of trapping sediment.
Geocellular structure	A plastic box structure used in the ground, often to attenuate runoff.

Green corridor	A strip of land in an urban area that allows wildlife to move along it and can support habitats. Typically includes cuttings, embankments, roadside grass verges, rights of way, rivers and canal banks.
Green infrastructure	A strategically planned and delivered network of natural and man-made green (land) and blue (water) spaces that sustain natural processes. It is designed and managed as a multifunctional resource capable of delivering a wide range of environmental and quality of life benefits for society.
Green roof	A roof with plants growing on its surface, which contributes to local biodiversity. The vegetated surface provides a degree of retention, attenuation and treatment of rainwater, and promotes evapotranspiration. Sometimes referred to as an alternative roof.
Groundwater	Water that is below the surface of ground in the saturation zone.
Habitat	The area or environment where an organism or ecological community normally lives or occurs.
Highways Agency	The Government agency responsible for strategic highways in England, ie motorways and trunk roads. This is undertaken by Transport Scotland in Scotland, Department of Economy and Transport in Wales, and the Northern Ireland Roads Service.
Highways authority	A local authority with responsibility for the maintenance and drainage of highways maintainable at public expense.
Impermeable surface	An artificial non-porous surface that generates a surface water runoff after rainfall.
Impermeable	Will not allow water to pass through it.
Infiltration (to the ground)	The passage of surface water into the ground.
Infiltration basin	A dry basin designed to promote infiltration of surface water to the ground.
Infiltration trench	A trench, usually filled with permeable granular material, designed to promote infiltration of surface water to the ground.
Masterplan	A masterplan includes both the process by which organisations undertake analysis and prepare strategies, and the proposals that are needed to plan for major change in a defined physical area.
Micropool	Pool at the outlet to a pond or wetland that is permanently wet and improves the pollutant removal of the system.
Monetised costs and benefits (tangible)	These are easy to understand and measure financially, eg the price of land or reduced damage costs to property.
Monitoring plan	Sets out the approach, timing and resources to monitor measures adopted.
Multifunctional space	An area that has more than one use, one being to manage surface water.
National Standards for Sustainable Drainage	Also referred to as the National Standards. A regulatory document providing Standards and guidance on the design, construction and maintenance of SuDS for approval and adoption by the SuDS Approval Body.
Net present value (NPV)	The difference between the discounted costs and benefits over the appraisal period.
Nibbling	See *opportunistic retrofitting*.

Non-monetised costs and benefits (intangible)	These are difficult to define clearly such as the pain of suffering, loss or inconvenience.
Non-wholesome water	Water not suitable for drinking and has the same meaning as in Part G of Schedule 1 to the Building Regulations 2000 (SI 2531/2000) (as amended).
Optimism bias	This is an allowance for too much optimism in the costings or too many or too quick realisation of benefits, so an explicit adjustment is made that should be empirically based and sensitivity analysis to test assumptions.
Opportunistic retrofitting	Where the opportunity to retrofit SWMM arises on the back of other drivers, such as regeneration or small scale improvements. These may occur within a neighbourhood, or locally on a plot level.
Pathway	The route by which potential contaminants may reach targets or by which water (and pollutants) are conveyed either below or above ground.
Pavement	The road or car park surface and underlying structure, usually asphalt, concrete, or blockpaving. Note: the path next to the road for pedestrians is the "footway" (the UK colloquial term of pavement).
Penstock	A sliding plate that moves vertically to vary the size of an aperture (or close it completely).
Percentage runoff	The proportion of rainfall that runs off a surface.
Percolation	The passing of water (or other liquid) through a porous substance or small holes (eg soil or geotextile fabric).
Permeability	A measure of the ease that fluid can flow through a porous medium. It depends on the physical properties of the medium, eg grain size, porosity, and pore shape.
Permeable pavement	A permeable surface that is paved and drains through voids between solid parts of the pavement.
Permeable surface	A surface that is formed of material that is impervious to water but, by virtue of voids formed through the surface, allows infiltration of water to the sub-base through the pattern of voids, eg concrete block paving.
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 is injurious to existing, intended, or potential uses of the resource.
Pond	Permanently wet depression designed to retain stormwater above the permanent pool and permit settlement of suspended solids and biological removal of pollutants.
Porous paving	A permeable surface that drains through voids that are integral to the pavement.
Potable/mains water	Water company/utility/authority drinking water supply.
Prevention	Site design and management to stop or reduce the occurrence of pollution of impermeable surfaces and to reduce the volume of runoff by reducing impermeable areas.
Public sewer	A sewer that is vested and maintained by the sewerage undertaker (see Paragraph 219(1) of the Water Industry Act 1991).

Rain garden	A planted basin designed to collect and treat surface water runoff.
Rainwater butt	Small scale garden water storage device that collects rainwater from the roof via the drainpipe.
Rainwater harvesting or rainwater use system	A system that collects rainwater from where it falls rather than allowing it to drain away. It includes water that is collected within the boundaries of a property, from roofs and surrounding surfaces.
Receptor	A location that is subject to an impact either through flooding or pollution. Certain types of measures can be retrofitted at such locations.
Recharge	The addition of water to the groundwater system by natural or artificial processes.
Retention pond	A pond where runoff is detained for a sufficient time to allow settlement and biological treatment of some pollutants.
Risk assessment	"A carefully considered judgement" requiring an evaluation of the consequences that may arise from the hazards identified, combining the various factors contributing to the risk and then evaluating their significance.
Risk	The chance of an adverse event. The effect 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	Water flow over the ground surface to the drainage system. This occurs if the ground is impermeable, is saturated or rainfall is particularly intense.
Sewerage undertaker	A collective term relating to the statutory undertaking of water companies that are responsible for sewerage and sewage disposal including surface water from roofs and yards of premises.
Soakaway	A subsurface structure that surface water is conveyed into, designed to promote infiltration.
Source control	The control of runoff at or near its source.
Source	The location where surface water generated as runoff originates from, and can be controlled, see *Source control*.
Storm events	Events occurring between 1 in 1 year (100 per cent chance of occurring in any one year) and 1 in 30 year return period (3.3 per cent chance of occurring in any one year). These events are typically what urban drainage systems (below ground) are designed up to, and which flooding occurs.
Strategic Flood Risk Assessment (SFRA)	A SFRA provides information on areas at risk from all sources of flooding. The SFRA should form the basis for flood risk management decisions, and provides the basis from which to apply the sequential test and exception test (as defined in CLG, 2010) in development allocation and development control process.
Strategic retrofitting	Where a SWM driver is present, say to reduce flooding or improve the quality of a river. Here a wider approach across a neighbourhood or catchment may be taken to retrofit SWMM.
Sub-catchment	A division of a catchment, to allow runoff to be managed as near to the source as is reasonable.

SuDS Approval Body	An organisation likely to be formed by an upper tier or unitary authority responsible for the approval and adoption of drainage schemes in accordance with the National Standards for Sustainable Drainage.
SuDS management train	The management of runoff in stages as it drains from a site.
Surface water	Water that appears on the land surface, ie lakes, rivers, streams, standing water and ponds.
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 particulate matter. Treatment improving the quality of water by physical, chemical and/or biological means.
Treatment stage	A component of a sustainable drainage system improves the water quality of the water passing through it.
Waste	Any substance or object that the holder discards, intends to discard, or is required to discard.
Water Framework Directive (WFD)	A European Community Directive (2000/60/EC) of the European Parliament and Council designed to integrate the way water bodies are managed across Europe. It requires all inland and coastal waters to reach "good status" by 2015 through a catchment based system of River Basin Management Plans, incorporating a programme of measures to improve the status of all natural water bodies.
Water sensitive urban design (WSUD)	The integration of water cycle management into urban planning and esign.
Water table	The point where the surface of groundwater can be detected. The water table may change with the seasons and the annual rainfall.
Watercourse	A term including all rivers, streams, ditches, drains, cuts, culverts, dykes, sluices, and passages that water flows through.
Wetland	Flooded area where the water is shallow enough to enable the growth of bottom rooted plants.

Abbreviations and acronyms

AONB	Areas of Outstanding Natural Beauty
BAP	Biodiversity Action Plan
BCR	Benefit cost ratio
BMP	Best management practice
CABE	Commission for Architecture and the Built Environment
CBA	Cost-benefit appraisal
CDM	Construction (Design and Management) Regulations (1994)
CFMP	Catchment Flood Management Plan
CIWEM	Chartered Institute of Water and Environmental Management
CSO	Combined sewer overflow
DCLG	Department for Communities and Local Government
Defra	Department for Environment, Food and Rural Affairs
DTi	Department for Trade and Industry
EA	Environment Agency (England and Wales)
EC	European Commission
EDD	Engage-deliberate-decide
GI	Green infrastructure
GIS	Geographic information system
GS	Global sustainability
LA	Local authority
LiDAR	Light detection and ranging
LID	Low impact development
LS	Local stewardship
MEA	Millennium Ecosystem Assessment
NE	National enterprise
NPV	Net present value
Ofwat	The Water Services Regulation Authority
PV	Present value
RBMP	River Basin Management Plan
RoSPA	Royal Society for the Prevention of Accidents
SAB	SuDS Approval Body
SEA	Street edge alternatives
SEPA	Scottish Environmental Protection Agency
SFRA	Strategic flood risk assessment
SSSI	Sites of Special Scientific Interest
SuDS	Sustainable drainage systems
SWM	Surface water management
SWMM	Surface water management measures
SWMP	Surface water management plan
SWMS	Surface water management strategy
TCPA	Town and Country Planning Association
TPO	Tree Preservation Order
UKWIR	United Kingdom Water Industry Research Limited
USEPA	United States Environmental Protection Agency
WFD	Water Framework Directive
WLC	Whole life cost
WQ	Water quality
WSUD	Water Sensitive Urban Design
WM	World markets

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