Appendix B

Response groups – intra-urban

In Appendix A we described responses to flood risk that can operate at the catchment and coastal scales. In this appendix we describe intra-urban responses – those that can influence localised flood risk at the level of individual buildings, villages, towns and cities.

Intra-urban responses are identified and classified into a hierarchy of six groups – these generally reflect the spatial scales over which the various responses operate.

As in Appendix A, the following descriptions are provided for each response group:

- A definition of the response group and its function and efficacy in reducing flood risk.
- Issues of governance and performance in terms of sustainability.
- Costs and funding mechanisms.
- Interactions with other responses.
- Where appropriate a case example and comments on emerging issues concerning the response group.

The sustainability performance of each response group is also considered in terms of six sustainability metrics (see Chapter 1):

- Environmental Quality.
- Social Justice.
- Robustness.
- Precaution.
- Flood risk reduction.
- Cost effectiveness.

As before, the scores achieved by each response group (expressed in terms of the six metrics) are presented in this Appendix as spider diagrams.

A list of the response groups is as follows:

Urban Response Group B1 – Building Development, Operation and Form

Urban Response Group B2 – Urban Area Development, Operation and Form (Including Sacrificial Areas)

Urban Response Group B3 – Source Control and Above-Ground Pathways

Urban Response Group B4 – Groundwater

Urban Response Group B5 – Storage Above and Below Ground

Urban Response Group B6 – Main Drainage Form, Maintenance and Operation

It is recognised that certain of the catchment scale responses considered in Appendix A are also applicable to the urban environment – for example the themes Managing Flood Events and Managing Flood Losses. These are not covered further in this Appendix which instead, concentrates on responses specific to intra-urban flooding.

Response Group B1

Building Development, Operation and Form

Definition

The response group Building Development, Operation and Form includes opportunities to manage local flood risk though actions taken at the building level.

This Response Group also includes: the curtilage surrounding the building, floods originating from outside the curtilage as overland flow or from groundwater within the curtilage. Responses from the various stakeholders are also included (i.e. individual behaviour) together with responses that relate to actions when flooding does occur (mitigation).

Measures in the response group

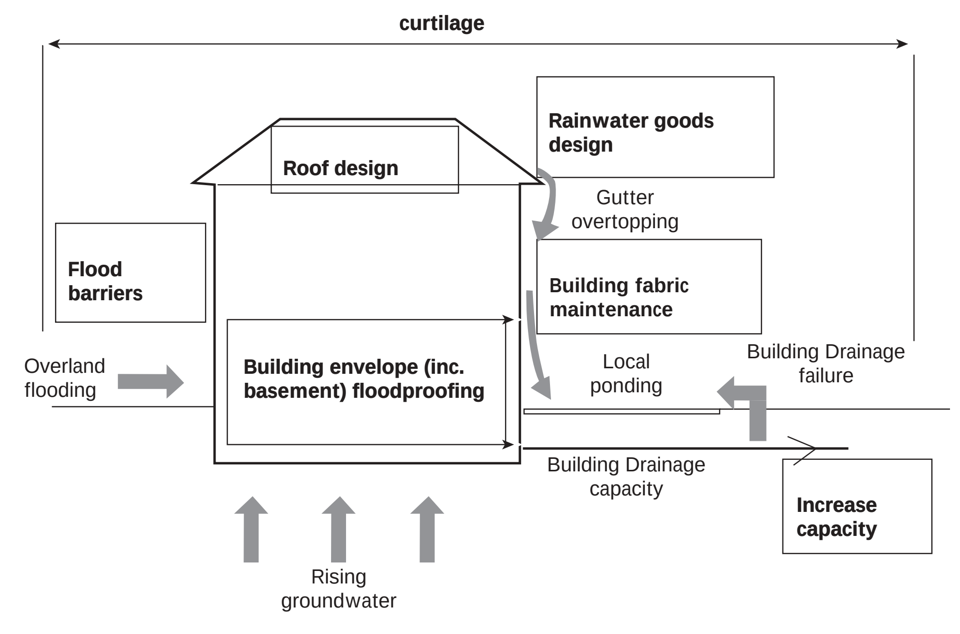
- Design of building drainage (inc. green roofs etc).
- Managing urbanisation (specifically in terms of building development and form).
- Floodproofing individual buildings/parts of buildings including local flood protection (freestanding temporary barriers; removable household products etc.).
- Rainwater harvesting and local use of stormwater.
- Changing building and local area drainage standards.
- Road gully inlets control.
- Disconnection of property downpipes.
- Ponding on roofs.

There are overlaps with other urban area response groups.

Function and efficacy

Opportunities to manage flood risk at the building level require an holistic and integrated approach with responses dealing with the spatially diverse risks. Typically this has to include existing buildings, of a variety of types and in various condition, and new buildings. The latter may be designed using concepts of new low-impact development (LID), where there is local use of water utilisation, using roof water to flush WCs for example.

Figure B1 **Potential failures and responses at the building level**



Failures in rainwater control may occur, and require responses, in a number of places (see Figure B1). In terms of solutions at the building level, the need is to secure and protect the building envelope and to reduce the downstream flood risk (e.g. ODPM, 2003).

Such measures could, in extreme cases, involve radical upgrading of existing buildings, for example with the building being strengthened and extended upwards to provide accommodation above flood level. It could also involve the radical re-design of new buildings to reduce the impacts of flooding. Other options may entail floating properties, as is done in Portland, Oregon, for example. The take-up of these measures will depend on the balance between costs and risks, and the pressures on land and location.

The effectiveness of responses depends on whether they are being incorporated into new buildings or being retrofitted into old buildings; the type of building; and location of the flood risk in the local area drainage system. At the roof level, assuming the roof structures are sound, there are risks when rainwater goods are overloaded. Attempts to attenuate water flows – through, for example, ‘green’ roofs and impermeable ‘ponding’ roofs – have previously been unsuccessful in the UK. This has primarily been due to leakage caused by thermal stress and movement and/or inadequate workmanship.

Many prestigious new developments seek to remove the rainwater quickly via siphonic systems. The consequences of failure of siphonic systems, in particular, can be more serious should the water flow exceed structural or mechanical limits. Roof drainage has typically been designed to accommodate storm events with a probability of occurrence in a given year of 1 in 30. However, current methods of specification now allow for different roof designs (nominally flat or sloping), gutter types and recognition of the ‘degree of security’ required (BS EN12056-3).

Both existing and new building stock had/has a typical intended lifetime of some 50 years or more. The associated drainage will have a shorter life. There is therefore the potential for a mismatch in the component parts of any integrated approach.

To prevent exacerbating downstream effects, the focus of roof-drainage systems may have to include abatement and attenuation. Downstream effects arise from flow interactions at surface level and, in the case of roof-siphonic systems, intermittent pulsing effects. For both conventional and siphonic systems, there is therefore a need for alternative strategies, including, for example, storage, attenuation and diversion of discharge in and around the building. Where no storage area is available, it may be necessary to identify sacrificial areas. Furthermore, discharge pumping of floodwater should be undertaken only within the constraints imposed by the external environment to avoid worsening downstream effects.

The susceptibility of a building to damage due to inundation will also depend upon its age and construction. Older brick and stone-built buildings are generally more resilient to recovery than many modern constructions particularly those built in the 1950s-1970s.

Currently, the building envelope may permit water or moisture ingress at various points. Flood damage can be compounded by coincident failure of the roof or building drainage system, or through the presence of excessive impermeable surfaces, such as paving, driveways, patios and so on. Securing the building against water ingress could involve the integration of flood barriers, impermeable membranes or self-sealing building components.

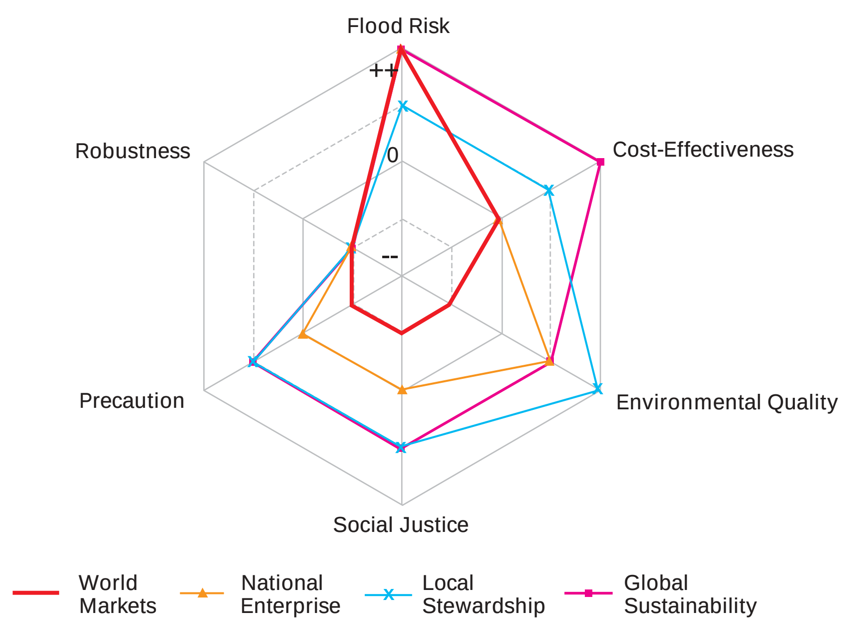
Discharges from roof-drainage systems into local drainage will affect flow conditions downstream in both separate and combined pipework and in other surface-water drainage systems. The more common older combined sewer systems will have the least spare capacity for adaptation to cope with future risk changes. Discharges from buildings and interactions of local flows within the curtilage will also affect the potential for surcharge, blockage or overflow, with the associated possibility of ground contamination.

Overall, when the largest events occur the success of these responses may be good locally, at the building level, but less so for the curtilage and wider catchment.

Governance and sustainability

An integrated building approach that meets targets for water conservation and sustainability while ensuring adequate performance of both the building and local drainage system will require closer collaboration between the Building Regulations Advisory Committee and the body that succeeds the Water Regulations Advisory Committee. There are now signs that this is beginning to happen. Enhanced collaboration will also be required with respect to Building Regulations (ODPM, 1992, 1992a; Scottish Executive). A fundamental role here will be to address the needs and responsibilities of householders, property owners and property developers, particularly with regard to building form and land management. This also integrates with planning agencies that will be key in contributing to the inclusion of attenuation and appropriate building form.

Building Development, Operation and Form



The most effective responses may be achievable for the larger buildings or groups thereof. For example, on-site stormwater management for a large hospital may be very effective compared with that for individual houses. However, given that standards are unlikely to change from building protection for up to 30 year events, drainage systems are likely to continue to fail at a frequency that will affect buildings, the local drainage system and the catchment as a whole. However, the cyclical review of the Building Regulations means that these will probably be reviewed before 2030, so it may not be a problem, depending upon the perceived rate of climate change.

There is still ambiguity in responsibilities regarding local flooding due to external inundation, muddy flooding, and flooding from watercourses in urban areas. In England and Wales, recent changes in the designation and management of Critical Ordinary Watercourses (COWs) by the EA and local authorities should improve this.

As the whole range of stakeholder groups use property directly, we need to consider the proposed solutions in terms of their impact on physical and mental health, costs, insurance and the impact on property and land cost.

Costs and funding mechanisms

The burden of costs will fall largely on the property owners, including large corporate bodies, and councils. However, depending upon the political drivers, local authority grants may be provided, as in the case of insulation and roof refurbishment. Given the UK's current building stock, associated infrastructure and mix of technologies, it is difficult to assess the cost of solutions.

Interactions

There are interactions between this response group with Urban Response Group B2, Urban Area Development, Operation and Form and with the response groups concerning source control (B3), storage (B5) and drainage form (B6).

Case example

A major retail centre in England was suffering from flooding of a car park adjacent to the store due to the rapidity with which roof drainage was conveyed from the large roof surfaces. Alternative outlets provided in the form of vortex controls, temporarily held back water on the roof areas, preventing flooding of the car parks.

Emerging issues

These include the extensive plans for new housing – particularly in the south of the country – the introduction of house condition logbooks, and continued building on flood plains. Some initiatives for low impact developments would integrate approaches to the water cycle locally. In future, climate change may encourage local initiatives on water use, particularly in water-scarce areas.

It is significant that the current round of price reviews for water service providers in England and Wales, has led to criticisms that companies have not adequately addressed demand management. There are also issues about the perception/assumption/acceptance of responsibilities of property owners and users and the likely adoption of local drainage by sewerage undertakers within the next decade.

Response Group B2

Urban Area Development, Operation and Form (Including Sacrificial Areas)

Definition

The response group Urban Area Development, Operation and Form concerns the potential to influence the risk of flooding within urban areas through changes in urban form and development.

Measures in the response group

- Improving or extending ‘traditional‘ flood embankments.
- Promotion of ‘green‘ spaces.
- Local flood barriers (transfer water).
- Controlling new development.
- Building regulations for flood risk areas to require flood mitigation strategies.
- Abandoning properties most at risk.
- Sacrificial local storage areas.
- Local and community protection of ‘islands’ within urbanscapes (temporary).
- Abandoning built areas most at risk.

There are overlaps with other urban area response groups.

Function and efficacy

Even a modest degree of urbanisation will change the hydrological behaviour and runoff characteristics of a catchment. For a typical UK town, with up to 40% impervious surfaces, some 20 to 50% of the initial rainfall ends up in the main drainage network. Strategic management of hard surfaces (and runoff) is therefore likely to be very effective at reducing flood risk.

Even where there is control over urbanisation, ‘creep’ adds hard surfaces in an uncontrolled and unpredictable manner. For example, a recent study showed that creep added some 2 to 8% to the impermeable area in three example catchments. The responses that are most likely to be effective are considered below.

The usual approach in urban areas entails increasing the conveyance of urban river channels and increasing the height of flood banks – that is, investing in 'traditional' flood defences – and not necessarily being concerned with the consequent sustainability issues. The main risks associated with this approach are the impacts of catastrophic failure and the potential for loss of life. It is possible that new materials/technology could mean that this type of defence becomes much more cost effective and sustainable in future, leading to much more extensive use of this form of formal flood defences under certain scenarios.

Strategies need to vary at a national level between: strongly developing urban areas, in particular in the south, that will lead to further compaction and restructuring in urban areas; and those losing population, for example, in the north. In the former, the opportunity for flood storage may be reduced and strategies required on a regional and city level to improve conveyance and storage of floods outside the built areas in functional floodplains and green belt areas. Such strategies might include the creation or restoration of wetlands – as in the USA.

Government wishes to direct new development to previously developed 'brownfield' land which may be in flood plains. In post-industrial urban areas, where development pressures are lower, and which may even shrink, opportunities for flood storage and infiltration may be better, including abandonment and sacrificing areas. Preservation of greenspace, including 'brownfield sites' or derelict land, is of particular importance and may provide good options for flood storage.

Within urban areas, the creation or restoration of coherent greenspace networks for flood storage and conveyance offers significant potential. Coherence provides linked corridors that may be utilised for conveyance, as original watercourses did. The hydrological role of functional river floodplains is evident, but disturbance corridors such as motorways and ring roads may also act as temporary storage and as a conveyance during extreme floods. Disruption to traffic would probably cause less damage than flooding of residential areas.

The types of city neighbourhood offer different opportunities to reduce flood risks, generally related to building density and the amount of impervious surfaces. Inner cities have little space for storage and infiltration. Preservation of existing greenspace, as well as consequent greening of streets and roofs, can be locally efficient measures to delay runoff.

Policies promoting the unsealing of impervious surfaces in commercial zones – such as car parks around shopping centres – offer opportunities for increasing infiltration. In low density housing areas, densification needs to be better controlled to avoid further loss of greenspace or private gardens. Finally, urban fringe areas, including Green Belt areas, could be assigned a particular role to reduce flood risk, and give them new value.

An understanding of the possible functions of land can reduce flood risk. As the value of land increases, so does the need to consider different roles for the space. Green space can, for example, fulfil storage and infiltration roles as well as leisure and amenity. The importance of developing multifunctional greenspace networks in towns and cities is increasingly recognised, for example by the Commission for Architecture and the Built Environment.

Governance and sustainability

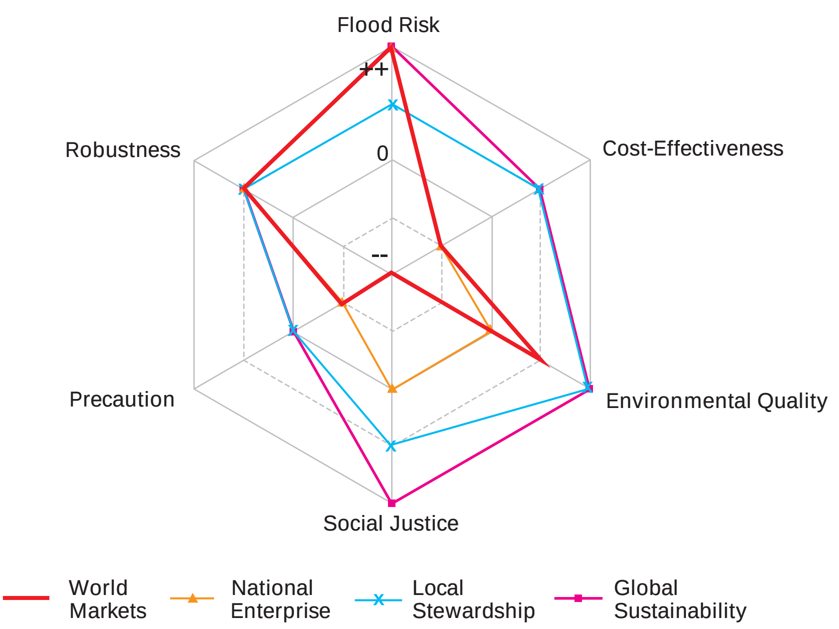
On the strategic level, national government is setting the agenda for urban development in the form of Planning Policy Guidance (PPG) and building regulations. It does this to enhance adaptation of urban form and reduce flood risks. Various PPG Notes – PPG3 on housing and PPG25 on development and flood risk – can have different implications for urban flood risks. The former advocates more compact housing while the latter sets out to limit runoff. There is an opportunity to rethink the guidance through new Planning Policy Statements (PPS) which are progressively replacing PPGs as part of the reform of the planning system (DTLR, 2001).

There should be consideration of the relationship between new settlements and water resources. At present the governance of such proposals does not fully consider water resources and possible consultees such as Water UK and the Water and Sewerage Companies could usefully play a role in the development process.

Government policy is that water and sewerage services can be provided anywhere and these services can be provided within developments. However ensuring sustainability can be difficult. At present the utilities must provide these services and the Environment Agency, the statutory consultee, has to manage the environmental impacts in liaison with the service provider. It is clear that better tools are needed to ensure that the best case is made for the environment and sustainability within the planning process.

Land-use planners need to be able to review the sustainability of developments in a holistic and effective way, and the planning process, and associated decisions, need to be transparent and well balanced. Nonetheless, in any given situation, the overall balance of sustainability may over-ride water sustainability issues. In these cases, the land-use planning process should allow time for the development of sustainable service provision. This should be achievable by 2080.

Urban Area Development, Operation and Form



The regional level of planning may offer opportunities to influence urban form and development. Regional Assemblies will be required to produce a Spatial Strategy for their region and Regional Development Agencies have financial means and can stimulate interventions into the urban fabric.

Local authorities can influence urban form and development by a number of policies, programmes and plans. These include both formal policies and informal instruments, such as negotiation of planning obligations through Section 106 Agreements as part of their development function.

Enabling local communities to influence planning and decision making more effectively will be an important step to achieve a more sustainable urban form and development. Local Agenda 21 and Community Strategies are means to achieve this goal, as is the current drive to increase transparency in the planning process and with it more effective stakeholder participation. There is increasing evidence on the relationship between urban form and natural process, especially with regard to hydrological performance. However, this is not fully understood and therefore not properly utilised in urban planning in the UK. Development of tools to improve access to and communication of scientific knowledge is therefore required.

A possibility in flood areas would be to require developers – through a Section 106 Agreement, for example – to introduce measures to ensure that new development is 'flood neutral'.

Costs and funding mechanisms

Possibilities:

- Reallocation and more creative use of existing budgets – for example, for flood defence but also other sources such as the use of funds from Common Agricultural Policy to increase flood storage in green-belt areas. Insurance companies could allow resilient reinstatement and discounts for flood resistant property, Local Authorities could also provide grants.
- Market-based approaches – for instance by charging private house owners who wish to build in flood risk areas, linking development with flood prevention, for example using planning obligations to restore and create wetlands.
- The consequences of upstream development which increases flood risk elsewhere: methods could be introduced to fund measures to create compensational storage and environmental capacity.
- A greater understanding of the differences between flood source and flood impact areas could enable different funding mechanisms to be utilised. For example, a tax on flood-plain development could directly enable new defences to be built, while sites which generate large volumes of runoff could also be required to pay for the increased risk they contribute.

Interactions

There are strong links between this response and the responses dealing with Building Development, Operation and Form (B1) and Source Control, Above-Ground Pathways (B3) and Storage Above and Below Ground (B5).

Case example

Strategic green-space planning is called green-structure planning in the Netherlands to reinforce the idea that green space is as essential as the transport network, the electricity grid or water supply systems to the functioning of urban areas. In the past, traditional engineering approaches were used in a particular Dutch city to control surface-water flows. However, a more integral approach has now been adopted, in which green-space planning plays a strong role. On the city level, the green-structure plan provides a clear vision for the creation of a coherent network of linked green spaces. Streams and canals play a special role in this concept for storage and conveyance of water. Moreover, the city aims to protect the lowlands north of the city that have important functions for water storage during floods. It aims to reduce the artificial drainage of this area for farming to reduce problems further downstream. A means to implement the green-structure plan is to link development with green-space planning. For instance, the creation of a small 6-hectare park, which is not only important for recreation but was also designed for water retention, was financed by selling land for the extension of a car park of a hospital in another part of the city.

Emerging issues

These include:

- Changes in the governance system, such as the current reform of the planning system which may improve the prospects for adaptive responses but which are so far untested and unproven.
- Conflicting regulations, for example PPG3 and PPG25 – can this contradiction be overcome to adopt urban development that reduces flood risks?
- Cultural changes, for example developers' attitudes and the preferences of private consumers for housing locations.
- The importance of either new development or retrofitting. Current planning guidelines provide an effective mechanism for influencing new developments, while the controls concerning retrofitting are less well established.

Response Group B3

Source Control and Above-Ground Pathways

Definition

The response group Source Control and Above-Ground Pathways includes the management of stormwater as close to the point of origin as possible.

The possible responses in this group include a range of drainage mechanisms, known as Sustainable Urban Drainage Systems (SUDS), to manage rainfall-runoff in ways other than through pipe networks

Measures in the response group

- Design of roads and gully pots.
- Source control and local sustainable water system management.
- Water reuse and recycling etc.
- Reopen culverted watercourses (daylighting).
- Controlling pathways of runoff.
- Pumping off site.
- Multiple drainage systems.
- Aesthetic use of water in the urban area.
- Detention ponds.
- Infiltration systems.
- Permeable land cover.

There are overlaps with other urban area response groups.

Function and efficacy

Source controls comprise a range of possibilities within the concept of a SUDS ‘train’. They can be ‘non-structural’ in that they may relate to behavioural changes at the points where runoff occurs. Thus the way in which householders and property owners, or facilities managers, operate their storm drainage systems can be significant.

Table B1 **Structural SUDS methods and significance at managing flood flows and volumes (based on recent UK research)**

Measure	Peak flow attenuation of extreme events	Volume reduction of extreme events
Green roofs	+ +	+
Water Butts	0	0
Domestic Soakaway/ Infiltration trench	+ +	+ +
Filter strips	+	0
Filter trenches	+	+
Swale	+	0
Under-drained Swale	+ + + +	+ +
Pervious pavement	+ + + +	+
Infiltration basin	+ + +	+ +
Detention basin	+ + + +	+
Retention pond	+ + + +	+
Wetland	+ +	+ +

Key: ++++ 80-100%; +++ 60-80%; ++ 40-60%; + 20-40%; O 0-20%.

Most non-structural 'source' controls have a greater influence on runoff quality rather than quantity and hence are not necessarily significant for flood management (Table B1). The hydraulic effectiveness of SUDS for extreme events is a function of their hydraulic design criteria and soil type. Hydraulic design criteria vary and therefore their ability to cater for extreme rainfall events ranges from very limited to being very effective.

All SUDS systems are more effective to some degree than pipe networks at controlling both quantity and quality of stormwater drained. The latter maximise the rate of runoff from a catchment, thus generally exacerbating flooding problems downstream, either locally or in the river. The effectiveness depends on two issues:

- Hydraulic criteria need to be applied that cater effectively for both small (frequent) and also large (extreme) events (which has significant cost implications).
- Space availability. The current trend focussing on sustainability/energy – reduction in car use and travel distances – resulting in policies such as PPG3, constrains the ability of SUDS to protect urban areas against flooding.

There are some limitations. Where SUDS and overland flood flow paths are within flood plains, or downstream of a flood source, their effectiveness will be nullified during river flooding. In fact, the use of

SUDS in these circumstances is likely to be worse than when using standard pipe systems, in that silt from fluvial flooding may block pervious pavements and grassed areas, filling swales and ponds, generally creating a serious maintenance problem. In theory, the creep in urbanisation may result in some SUDS surfaces becoming urbanised by careless home-owners.

In addition to their ability to protect against flooding, the long term performance of SUDS is related to effective maintenance management. As SUDS are relatively untested by time – even in France and Scandinavia, where they are now approaching the first 50 years – the long-term implications for costs of managing these structures to maintain their performance is not certain and this is a significant barrier to their utilisation. The National SUDS Working Group recently issued a draft protocol for the use of SUDS in England and Wales. This emphasised the problems of ownership and responsibility for maintenance. Most SUDS systems are not designed for large events. Only recently have structures such as ponds been designed to address events with an annual probability of 1 in 100. Where ponds are used and designed to such events, the reduction in peak flow can be of the order of 10 times, but it requires between 3 and 4% of the contributing catchment land take.

The most effective mechanism for addressing extreme events is attenuation with ponds, wetlands and so on, as limited infiltration can occur during the most extreme events, due to soil saturation and the limited period of flooding. Pervious pavements are also effective at attenuation, even where there is no underlying soil infiltration capacity, due to water percolation through the stone media. However, there are two types of extreme events; those that cause problems catchment wide, and those that are intense short storms affecting the local area. Although the responses of SUDS to both types of events will be much the same, the antecedent conditions will normally be different in terms of prior utilisation of the available storage. Thus SUDS will therefore be more effective in dealing with the second type of event.

The opportunities for SUDS differ between new developments and retrofitting them to existing urban areas. There are also differences between categories and densities of urban zones. Some units effectively have no footprint in that they can be underground. Thus carparks can have storage tanks underneath them to attenuate runoff. Alternatively pavements can be pervious. However, the land take of SUDS, when applied in a SUDS train for new residential developments, is typically around 10% of the area served. Thus SUDS can have considerable effectiveness to manage extreme events in new developments. However, the application of SUDS in heavily built-up existing developments will not become extensive, although it can be made to work, as is shown by a number of Japanese applications.

All drainage, however designed, will eventually ‘fail‘ when there is a sufficiently large event. In this circumstance water floods low lying areas and travels down roads and other paths of least resistance. Certain countries, notably New Zealand and Australia, have limited drainage capacity and have ‘designed in’ the concept of overland flood-flow pathways. These flood flows are mapped and produced as hazard maps. This has several implications:

- The population must be informed and must be able to accept the designed drainage routes.
- Insurance may be a problem for properties in the flood paths.
- The design tools now available have limited capability to predict this drainage routing accurately.
- An integrated approach must be taken to infrastructure design (roads and drainage) as well as planning (building floor levels).
- Selection of sacrificial flooding areas is required if suitable other temporary flood storage areas are not available.
- This approach to control flood pathways allows control of existing drainage systems to encourage flooding in one location to protect another. This implies real-time management of events, which increases the risk of liability of the operator.

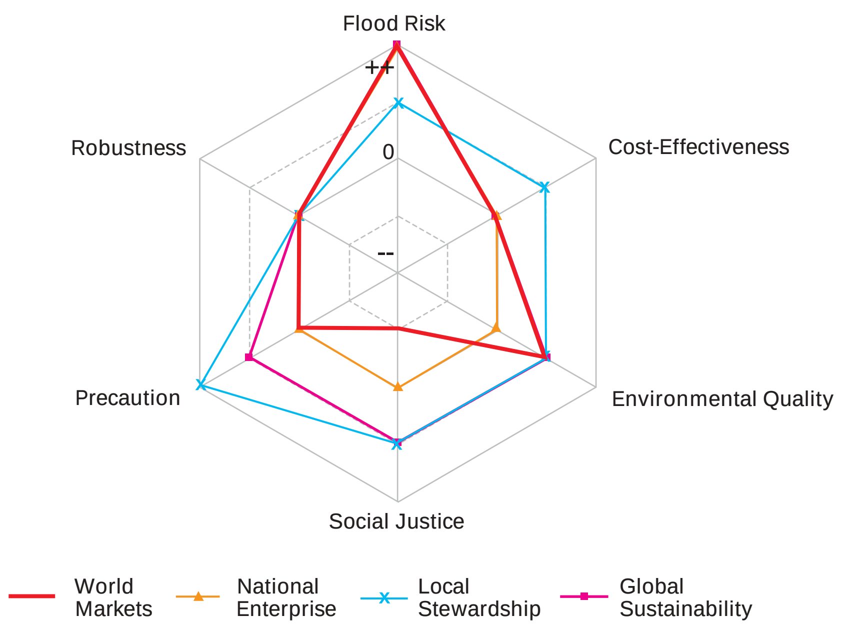
There is a need to ensure that these options are installed as standard in an appropriate way throughout catchments. By 2030 we need to have in place the tools to achieve this for the purpose of modelling and catchment-flow management, and to assist regulation. Alongside this we will probably need to have bigger, better traditional drainage systems under certain scenarios.

Governance and sustainability

The time frame for widespread implementation of SUDS is a function of the legislative framework rather than a limitation of the technology. This situation will probably improve over the next decade.

The responsibility for standard pipe drainage is clear, and is split between water companies, local authorities, highways authorities and private ownership. In contrast, SUDS are not ‘owned’ by any party at present, other than a private landowner. The main problem is the division of responsibilities between the various parties and the legal definitions of drainage. In addition, there are differences between the laws in Scotland and England, which may result in the solution to this problem moving in different directions in each area. For example, in Scotland, within two years there will be a 'SUDS for adoption' document. Whereas in England & Wales, there is currently a draft management protocol.

Source Control (+ above ground pathways)



Overland flood flows that cause damage are clearly a responsibility of the authority whose system 'failed', although riparian owners have a duty to accept 'upstream flows'. Water companies are now seriously concerned about their potential liabilities. This has been exemplified by the Marcic case where it was initially found that Thames Water had caused unacceptably frequent external flooding, outside but adjacent to a property. Although the House of Lords has now overturned this judgement, it is likely that the problem will continue, but with less immediate economic pressure.

It is clear that designing for overland flood paths has to be accurate and with little risk to the community. The idea of using sacrificial areas, flooding certain properties in preference to others, may therefore be unlikely in the light of the concept of 'equity' in meeting the objectives of sustainability and the Human Rights Act.

As sewerage undertakers are responsible for drainage management using pipes, their role in managing overland flow down roads is as equally unlikely as their current antipathy towards SUDS. The key here will be the attitude of the Highways Agency and local authorities. It seems unlikely that these issues will be successfully addressed in the UK without significant modification of the legal position on drainage responsibilities.

There have been very few UK studies of stakeholder awareness of the existence and purpose of SUDS or their acceptability to the community. There is significant resistance to their use due to the perception of increased health risk, though this reduces after the features become familiar. It was found that there is little awareness and understanding of SUDS and that it will need considerable effort to educate the public to understand the purpose and value of SUDS.

Assuming the governance and acceptability issues are resolved, the question as to whether SUDS are part of a sustainable solution to drainage problems seems incontrovertible. Recent research has investigated their whole-life cost, which has generally been shown to be cheaper (HR Wallingford, 2003). As they provide additional benefits of water quality and amenity compared with pipe based systems, SUDS can usually be seen to provide real advantages over traditional systems.

Costs and funding mechanisms

Recent studies of whole-life costs generally shows that SUDS are no more expensive than existing drainage systems. Maintenance costs are likely to be slightly greater, and require a different workforce and skills. As local authorities and sewerage undertakers already have mechanisms in place for funding services, this aspect does not require implementation of new methods to increase revenue. This assumes that problems of governance of SUDS are resolved. The cost of development and stormwater provision is now greater only because standards are rising. Thus flood-attenuation ponds are now designed for 100-year events, whereas 30 years conveyance with no flow restraint was the design criterion 20 years ago.

Interactions

Interactions exist notably with the urban response groups Urban Area Development, Operation and Form (B2), Building Development, Operation and Form (B1) and Main Drainage Form, Maintenance and Operation (B6).

Case example

In terms of the opportunities to retrofit SUDS, existing UK design guidance offers no help on the potential for retrofit. However there is a growing emphasis on the principle of sustainability in designing the solution to meet quantity, quality and amenity objectives.

The potential for retrofit of SUDS was investigated for two catchments in Leeds. The objectives were to minimise downstream flow volumes in terms of the discharges from combined sewer overflows. Direct comparisons between SUDS-based and conventional solutions showed that in both catchments retrofit SUDS could provide cost-effective hydraulic improvement, either as fully SUDS-based or partially SUDS-based rehabilitation strategies. In one case, a SUDS-based solution could provide the necessary hydraulic control, in terms of reduced spill volumes, at 50% of the construction cost of a conventional storage solution. Barriers to implementation exist, however, caused by institutional responsibilities and duties.

Emerging issues

The main issue is the debate in England and Wales about responsibilities for operation and maintenance. Legislative change might be needed – as in Scotland.

Response Group B4

Groundwater

Definition

The Groundwater response group entails management of groundwater in urban areas to allow infiltration during high precipitation, so preventing flooding; measures that prevent groundwater from rising to levels that flood basements and emergence on urban surfaces.

Note that infiltration is dealt with under source control and in Response Theme 2 of the wider catchment based responses, Managing the Urban Fabric.

Measures in the response group

- Controlling groundwater levels, by pumping for example.
- Maintaining sewer capacity by reducing infiltration from groundwater.
- Maintenance of permeable land cover.

There are overlaps with other urban response groups.

Function and efficacy

There are two important aspects here. The principal groundwater level, that underlying aquifers and/or the saturated zone, moves up and down, usually seasonally. In addition, there is also moisture in the upper levels of the soil and substrata. The capacity for the upper soil levels to accept infiltrating water, the soil-moisture deficit, is the difference between the soil's capacity to absorb water and the actual amount of moisture in the soil. When the soil-moisture deficit is low or zero, infiltration systems no longer function. In the future, higher ambient temperatures will create more dynamic interactions between the evaporation from the upper layers of the soil and any infiltrating flows.

No agency has statutory responsibility for recording groundwater flooding events (Simpson & Morris, 2004). However, in some areas of the country, the Environment Agency is developing large-scale groundwater models of chalk regions as part of its Catchment Abstraction Management Strategy (CAMS) process. In recent groundwater floods, there is evidence that groups of stakeholders identified the causes and remedies and produced solutions within water resources management partnerships. These partnerships are currently 'goodwill' actions

Solutions to groundwater flooding entail prevention, mitigation and prediction. Lowering levels locally involves, for example, french drains and other drainage, and for protection, local floodproofing and pumping. There is typically greater complexity in solutions based on managing groundwater than for, for example, managing river flooding (Fleming, 2002), which may include diversionary action that may impact downstream.

Groundwater management alone cannot materially influence flood risk. It has to be considered in relation to the inputs and outputs. Inputs may come from upstream aquifers, local infiltration systems, either direct infiltration or from adjacent rivers. The most useful approach may be to consider the conjunctive operation of groundwater for supply purposes together with the control of flood risk from rising groundwater and this may become easier in some areas as water resources management tools are developed as part of the CAMS process.

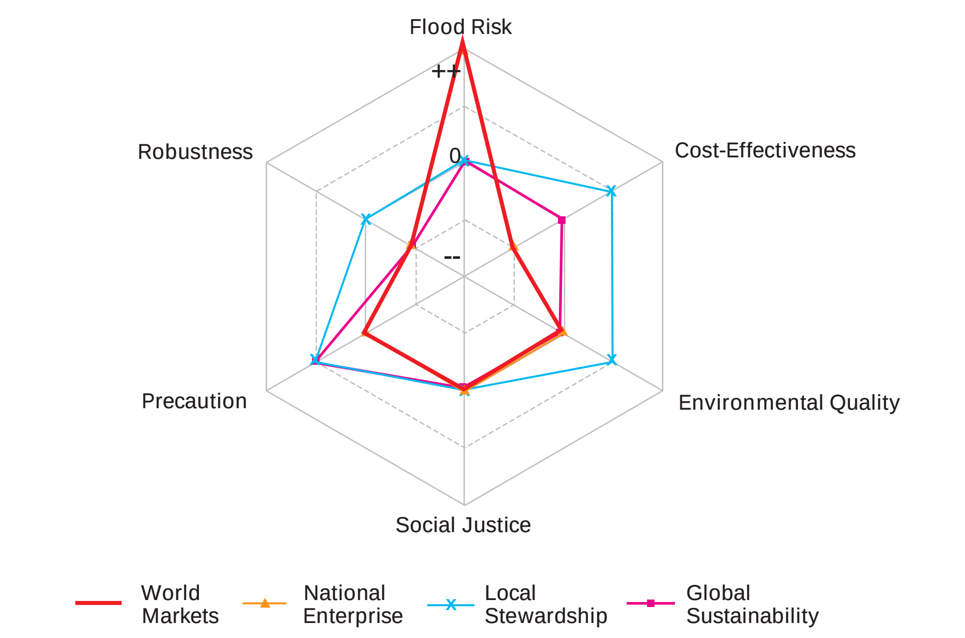
There may be an opportunity to infiltrate into the ground a similar amount of stormwater to what is abstracted from surface runoff. However, there is evidence that flood diversions may lead to risks of contamination of groundwater elsewhere. For example, in the 1997 floods in the Red River Valley in the USA, the contamination of groundwater by coliform bacteria was 'unprecedented'.

It is important to relate local management of groundwater to what happens in downstream watercourses. In general, flow through soils to a river, for example, will help to attenuate the speed at which flood waves arrive, compared with simply routing surface runoff through other control systems. It is not possible to generalise as to how effective this may be. The application of methods to manage groundwater in terms of flooding, both locally and the consequential downstream potential effects, is complex and usually local. It requires specialist skills and is likely to require the management of very large volumes of water, by pumping diversion or otherwise.

Where groundwater levels are high, there is higher risk of ingress into piped drainage. This is considered in Response Theme A2, Managing the Urban Fabric, for the wider catchment responses. It is also considered in Urban Response Group B6, Main Drainage Form, Maintenance and Operation. Where this is a problem, it is important to maintain the capacity of the piped drainage

The amount of permeable land surface in a catchment will have an important impact on relative groundwater levels. Within the urban area itself, an increase in paved surfaces may help to reduce groundwater levels, making it more practicable to use infiltration drainage systems (see also Source Control (B3)).

Groundwater Control



Governance and sustainability

No statutory body is responsible for groundwater flooding. Nonetheless it is likely that several agencies will be involved in groundwater management. The Environment Agency and the Scottish Environment Protection Agency are interested in terms of water quality and for flood warning. Also in England and Wales the Environment Agency are interested in groundwater flood protection when linked with other causes and despite PPG25 not fully addressing groundwater issues, the CIRIA project reviewing development and flood risk is likely to give greater prominence to groundwater in flooding risk assessments in the future (RP675, CIRIA 2003). This may place a greater burden on the Environment Agency in terms of Local Authority planning applications.

As the principal water service providers, the private companies in England and Wales, Scottish Water in Scotland and the Northern Ireland Water Services will be primarily responsible for attempts at conjunctive utilisation of the opportunity to supplement groundwater. Thus it will be important to ensure that local authorities and other agencies responsible for aspects of flood control can collaborate effectively, via perhaps the new roles of the environment agencies as managers of river basins. This response should be seen as part of a larger scale Integrated Water Management (IWM) response strategy as it needs to be fully integrated.

The management of groundwater must be seen as part of a perspective of the sustainable management of the subsurface. This is an integrated perspective that includes the economic value of the energy and mineral resources, as well as water. In countries like Holland, this is essential as there are competing demands for subsurface space. There are also social impacts, for example, in denying space to develop new below ground transport systems to maintain groundwater storage.

The management of groundwater to control flood risk is a long-term large-scale response, entailing large volume management with possible high-energy utilisation. It is likely that this type of response may be suitable only in areas where water is normally scarce at times of year. It is not likely to be a feasible response to ensure that local infiltration systems continue to operate.

Costs and funding mechanisms

In view of the lack of clear responsibility for groundwater flood control, the cost burdens would be shared between the various agencies in terms of their share of interest. At the local level, it may seem straightforward to infiltrate a small drainage area. However, it is likely to be very difficult to assess the implications in terms of contamination, contribution to rising or falling groundwater levels, consequences for impacts downstream. The proposals in RP675 (CIRIA, 2003) would mean that any development would have to consider at least the flow volume effects – as they affect the site under development and also as might affect downstream areas. Costs for manipulation of groundwater levels are likely to be very large.

Interactions

Interactions exist notably with Urban Response Groups B2 and B3, Urban Area Development, Operation and Form and Source Control and Above-Ground Pathways.

Case example

The Environment Agency has begun widening the Forebridge Rife river channel. This entails construction of a new outfall and modification of seven culverts as part of the River Lavant Flood Alleviation scheme in West Sussex to protect Chichester and the surrounding areas from the risk of heavy flooding. Chichester was under threat from rapidly rising water levels in 2000/1 and in 1993/4. In the latest event, some 13 miles of emergency pipeline had to be used to protect the city.

Emerging issues

The need to supply water to large planned developments, such as the Thames Gateway, may encourage the conjunctive management of groundwater.

Response Group B5

Storage Above and Below Ground

Definition

The response group Storage Above and Below Ground consists of providing additional storage volume – by physical structures above or below ground – to increase the potential for the urban drainage system to act as a flood-defence mechanism.

Measures in the response group

Storage volume can take several forms in an urban drainage system. The focus here is on in-sewer storage – the volumetric capacity of sewer network conduits – and tanks/ponds, with discrete storage provided by physical structures above and below ground. This group overlaps with that for source control.

Specific measures in this response group include:

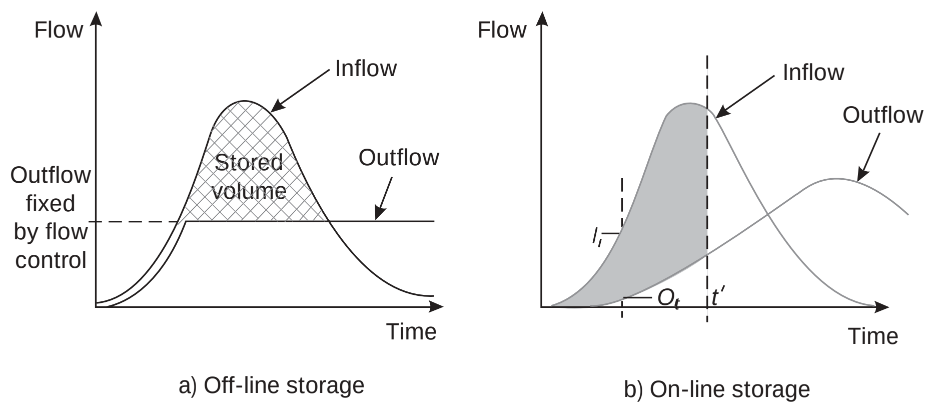
- Detention ponds.
- Mini-storage.
- Storage along or adjacent to flood system.
- Local ponding in flood-retention areas.
- Underground storage.
- Temporary flood storage, in parkland for example.

There are also informal storage elements within the urban landscape, where ponding can occur, including roads.

Function and efficacy

In an extreme rainfall/runoff event, the urban drainage system will need to handle flows above the designed maximum flow capacity. When the runoff rate exceeds the capacity of the sewers or other parts of the system, excess flow results in surcharged pipes, overflows from other parts of the system and eventually to surface flooding. Additional storage volume can temporarily store more runoff, reducing the frequency of flooding. Stored water is released back into the network over an extended time period, reducing the peak discharge flow, by more than 80% in some cases, achieving an attenuation effect (see Figure B2). This could be the most effective response measure in urban areas.

Figure B2 **The flow attenuation effect of detention storage volume**

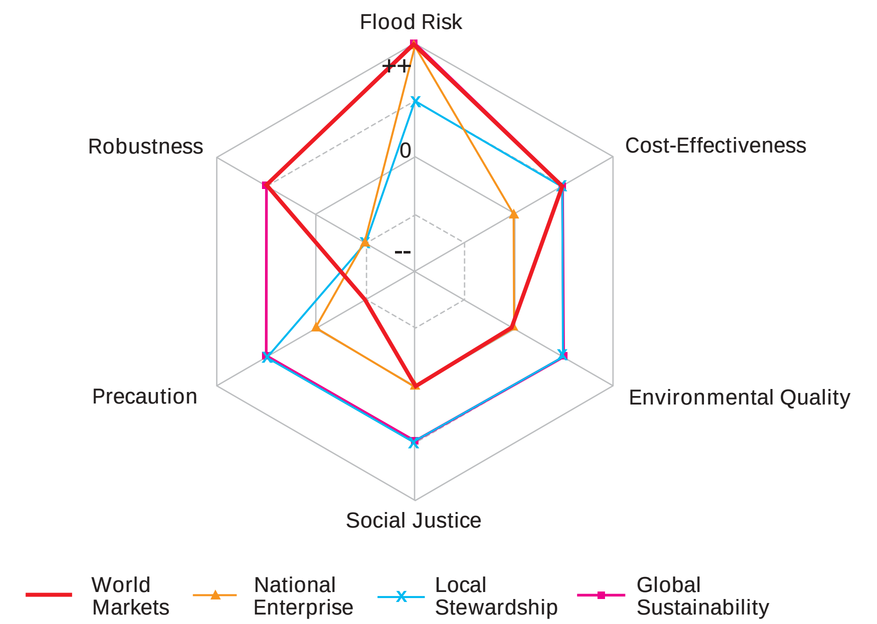


Below-ground storage schemes are designed to achieve standard flooding protection levels that depends on location, but not currently more than 30 years. The design life is 25 to 50 years, although many existing below ground structures are considerably older. There are very often considerable difficulties in retrofitting storage into existing urban areas (both above and below ground), due to space (and planning) limitations. This is less of an issue when providing storage in new developments, although there will always be pressure to minimise surface land take. There is limited experience that suggests the effectiveness of below ground storage tanks can be improved by utilisation of real-time control (RTC) systems. Storage above ground is now designed for 100-year storm events with PPG25 requiring consideration of downstream flood risk when these systems fail.

Governance and sustainability

Centralised, in-system storage is owned and operated by private water companies in England and Wales and by publicly owned Scottish Water and Northern Ireland Water Services. They are subject to regulation in terms of overflows – pollutant load, flow rate and volume – by the Environment Agency and the Scottish Environmental Protection Agency. Provision of centralised storage is a ‘top-down’ approach to urban flood mitigation which requires central governance and long-term capital expenditure programmes. There are difficulties with the ownership and operation of above ground storage as described in Urban Response Group B3, Source Control and Above-Ground Pathways.

Storage Above and Below Ground



Centralised storage is an engineering solution. It is effective in combating flooding and starts to contribute at maximum capacity immediately. Centralised storage is also expensive in terms of capital costs and material energy use. Lifetime cost assessment of in-system storage indicates this may be a poor solution in sustainability terms, although it has a sound track record with a well established effectiveness. If the system is coupled with real-time control – utilising scientific knowledge and current research – it could improve both flood control and river water quality. Even existing sewerage could be made more effective with real-time control maximising the use of spare capacity under extreme events.

Costs and funding mechanisms

Above-ground, surface storage schemes will typically require some 3-5% of the catchment plan area. Below ground storage is more costly – at least by an order of magnitude – although this will depend on land costs. Using tank sewers rather than tanks is even more costly, typically an additional 50%. It is common practice to provide storage for excess flow caused by small rainfall events but the provision of larger volumes for flood alleviation from extreme events is generally associated with substantial costs and is thus less common. Funding below-ground storage is the responsibility of the sewerage undertakers, whereas surface storage may be funded by a range of stakeholders, from individual property owners to councils and highways agencies.

Interactions

There is clear interaction between the storage responses and the source-control responses. Some measures can be categorised as being in both groups. Wide adoption of source-control responses, that is through more distributed storage and retention, could reduce the volumes that centralised storage has to accommodate and alter its main function, from being a storm-water flood-control strategy into a water quality control strategy as well as a back-up for extreme events.

Case example

An urban detention pond in Brazil is a good example of an above-ground stormwater storage pond (Nascimento, Ellis et al. 1999). This pond provides protection for a 10-year return period, reducing the 10-year peak flow by 65%. It also has the potential for multi-functional use with particular emphasis on recreational benefits.

Emerging issues

The wish by sewerage undertakers to increase assets means that there is a presumption on their part that below ground tanks are virtually the only solution to excess flows. The current difficulties with source control (SUDS) implementation in England and Wales also discourages alternative solutions. There is no incentive for sewerage undertakers to use other measures, despite the high costs, which are passed on to customers.

A study in Scotland, of a sewer flooding problem in a town centre, set out to see if widespread storm-water disconnections were feasible. Despite the potential sustainability, effectiveness and cost-saving of rainwater barrels and other local utilisation measures, an in-sewer storage solution was preferred as this was more robust. There were fears that future property owners would wish to reconnect to the main network. There were also building regulation problems for the alternative solution.

Response Group B6

Main Drainage Form, Maintenance and Operation

Definition

The response group Main Drainage Form, Maintenance and Operation consists of the physical form of the urban drainage system, its operation and operation with respect to the impact on flood control.

This response group can include pipes and other surface conveyance systems.

Measures in the response group

• System form	Sewer separation.
	Managing wrong connections.
	Limiting inflows by constricting inlets or surface disconnections.
	Limiting groundwater infiltration into sewers by rehabilitation.
	Localised non-return valves.
	Pump stations.
	Increasing pipe capacity (see also below ground storage).
• Operation	Real time control.
	Pumping.
• Maintenance	Planned and integrated.

Function and efficacy

With the exception of a few communities, the UK is almost 100% fully sewered. This existing asset base puts a huge inertia on innovations that require a different approach. Hence there is a momentum to extend sewerage systems to respond to capacity problems, increasing both storage and possibly reducing storm-water travel time. However, it is known that this approach is both expensive and questionable in sustainability terms. Nonetheless, under certain scenarios, such as World Markets it may prove to be attractive.

Modifications to the form of the system can be implemented in a number of different ways:

- Sewer separation has been considered and practised, particularly in the USA, as a way of reducing the frequency and severity of flooding in urban areas although the longer term benefits could be limited, particularly because it is difficult to keep systems separate.
- Managing wrong connections could reduce the problem, over time, of misconnections into the separate foul and storm pipes and would require a concerted management effort, rather than technical solution.
- Limiting inflows of stormwater by constricting inlets or disconnecting roofs and paved areas. (This is considered in more detail in Urban Response Group B Source Control and Above-Ground Pathways).
- Limiting groundwater infiltration by sealing cracks, fissures and joints in sewers will increase capacity for storm flows.
- Localised non-return valves may be used where system surcharge is frequent to avoid basement flooding.
- Specific pumping may be feasible away from an area at risk.

Apart from pumping, which is expensive and high in energy use and may simply pass the problem elsewhere, the most promising response in terms of system operation is real-time control as mentioned in Urban Response Group B5, Storage Above and Below Ground. This approach still requires ‘excess’ physical storage within the system to fully utilise and exploit the potential of real-time control.

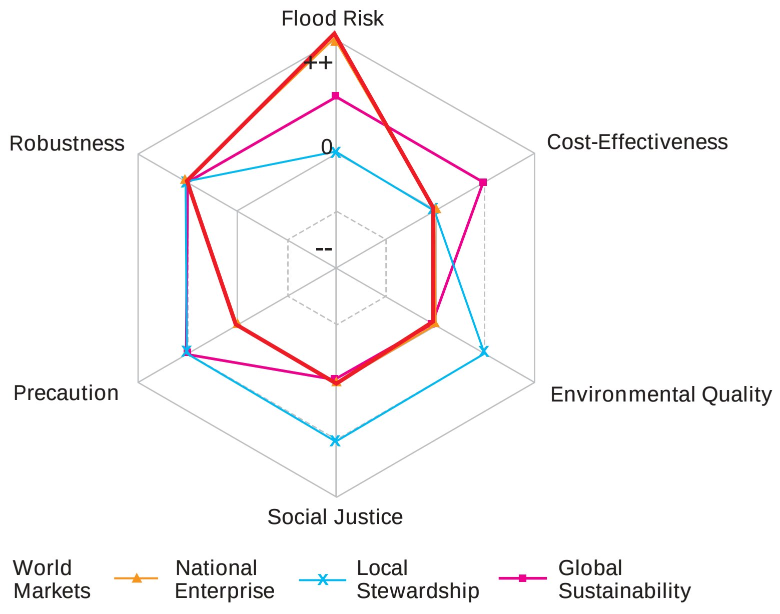
Proactive or planned maintenance of the drainage system is of interest to the water industry in the UK, which is looking to improve the condition and reliability of the system. This is in terms of the new serviceability approach being taken under Asset Management Plan 4 (AMP 4) in England and Wales.

The main link to flooding is through sewers that are in poor condition or where sediment and fat accumulate and significantly reduce the capacity of the sewer system. Better organised, prioritised and integrated maintenance could improve flood protection. The recent adoption of a ‘Common Framework’ approach to this in England and Wales should help in the future.

Governance and sustainability

The sewer network is owned and operated by private water companies in England and Wales and by publicly owned Scottish Water and Northern Ireland Water Services. Although there are trends for greater outsourcing, operators would be responsible for most of the works to be carried out to modify the system. The main exception is if extra effort is prioritised toward minimising wrong connections. At the moment, this would be controlled during building works by the building control officers of the local authorities, and so this function would require strengthening to be effective. For real-time control schemes, responsibility would reside with the sewerage undertaker, but implementation would require specialist skills and experience. Sewer maintenance is firmly the responsibility of the sewer owners, but is complicated by the fact that sediment enters the system mainly from highways and other paved areas, over which they have no control. Fats originate largely from restaurants. Fat and grease traps are often poorly maintained by owners. Regulation rests with local authorities, so the service provider has no direct control. Reduced sediment ingress could be expedited through additional gully pot cleaning and street sweeping, which are functions of local authorities or highways agencies.

Main Drainage Form, Maintenance and Operations



Dealing with a problem locally, through low-impact development (LID), is normally considered to be the more sustainable approach. Hence, it is potentially more sustainable to reduce stormwater inputs into the system than to build more separate sewer systems or to separate existing systems. Similarly, it is more sustainable to remove sediments and fats at source, perhaps by street sweeping and proper trap maintenance, rather than to let these mix with wastewater and stormwater in the sewer system. It is unwise, however, to label a particular technology or approach as 'sustainable' or 'unsustainable' because both low-tech and high-tech solutions will have their place, depending on context. This implies that real-time control solutions may be more sustainable, perhaps in densest urban areas that are already fully sewered.

Costs and funding mechanisms

Separate systems need larger trenches and additional pipes and are more expensive to construct than combined systems. However, the cost difference is not great. In addition, eliminating the need for storm tanks at downstream wastewater treatment works can make savings and give other benefits for receiving water quality. Separation of existing sewers is very expensive, particularly due to the extended disruption in urban areas. Real-time control implies expense in control mechanisms, automation and data transmission, but the reduction in storage needed by the system to deliver effective results may compensate for this increase. It may also be possible to reduce operating costs by optimising pumping and maintenance. Maintenance, however, becomes a more serious risk, as the system is less resilient to breakdown and requires specialist skills.

Interactions

Several of the options mentioned in this section are also covered in other responses: in particular, stormwater disconnection practices and real-time control systems. (In B1 and B5)

Case example

A study of an urban drainage system in Bradford, looked at the potential benefits of real-time control for flood and overflow reduction. Application was found to be somewhat problematic because parts of the catchment are steep and shorter travel times militate against beneficial control. For most events, however, there was a reduction in sewer overflow volume into urban watercourses, with the greatest benefit for more frequent, longer duration rainfall events. The performance of simple, local control strategies was broadly comparable with more refined 'global,' whole-system, strategies.

Emerging issues

The main issues in England and Wales are the need to maintain serviceability and the growing use of outsourcing. Despite the new common framework from United Kingdom Water Industry Research (UKWIR), some water service providers will not invest fully in serviceability under Asset Management Plan 4 – one, for example, will invest only up to 60% of what is needed due to the belief that ‘customers will not pay for more’. There may therefore be greater risks of sewer collapse and flooding in the period up to 2010, even under current climate conditions.

Outsourcing of virtually all functions has been apparently very successful in Wales. However, there are risks in loss of core knowledge by water service providers. There are also difficulties in implementing long-term plans where contractors have short-term contracts. There is a trend to use more pumping in systems. This is in part a response to the need to comply with the European Urban Waste Water Treatment Directive which required the abandonment of most coastal outfalls and pumping over long distances. For example the Tay wastewater scheme in Dundee pumps sewage some 20 km.

Storm-water management may become more localised in the future if the UK adopts more low impact development. This approach, which is becoming more common in the USA, Scandinavia and Germany, includes on-site recycling, reuse and direct use of roof water, for WC flushing, for example. This may cause problems downstream in large existing sewerage due to flows being too low to transport sewage solids.