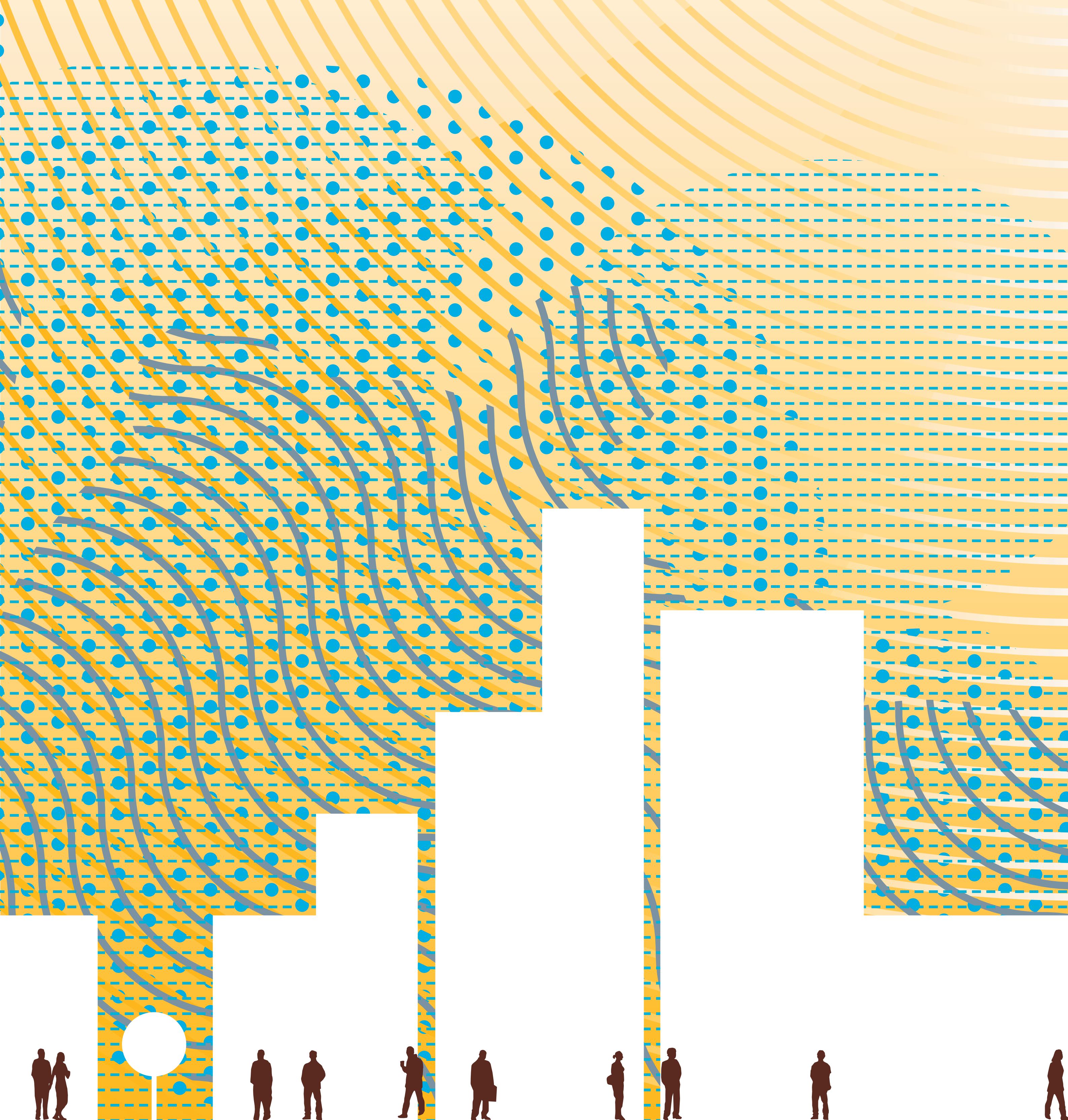
# climate change adaptation by design

a guide for sustainable communities



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The TCPA is an independent charity working to improve the art and science of town and country planning. The TCPA puts social justice and the environment at the heart of policy debate and inspires government, industry and campaigners to take a fresh perspective on major issues, including planning policy, housing, regeneration and climate change.

Our objectives are to:

- Secure a decent, well designed home for everyone, in a human-scale environment combining the best features of town and country.
- Empower people and communities to influence decisions that affect them.
- Improve the planning system in accordance with the principles of sustainable development.

tcpa

Commission for Architecture and the Built Environment

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English Partnerships
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RICS

# contents

# foreword

**There is now widespread scientific consensus that accelerated climate change is happening and that human activities are the principal cause. The unquestionable urgency of reducing greenhouse gas emissions now ranks alongside other pressing social and economic imperatives and is stimulating politicians, policy-makers and affecting the actions taken by developers, architects and urban designers. Public awareness is also greater than ever before, influencing lifestyle and purchasing choices. The TCPA continues to be at the forefront of the climate change debate.**

However, measures to reduce emissions are only part of the climate change challenge. Even if we make significant reductions in emissions tomorrow, the lag in the climate system means that emissions we have already put into the atmosphere will continue to affect the climate for several decades to come. The impact on towns and cities and their inhabitants will be significant – be it through uncomfortably high temperatures, greater incidences of flooding, strain on water resources and quality, or less stable ground conditions. Adapting to climate change is therefore an essential part of ensuring our communities remain desirable places to live and work.

Without an understanding of both mitigation and adaptation there is a real danger that actions taken to address one could actually make the other worse. We can illustrate this by looking again at the need for a range of densities of development: higher densities have been promoted as a way of improving the overall energy efficiency of the urban area. However, if density is too high this can exacerbate the urban heat island effect and increase the likelihood of urban flooding.

Responding to climate change adaptation requires space within and around buildings. If designed well, with innovative use of tree cover and landscaping, this can provide parallel opportunities to lower carbon emissions, improve air quality and create spaces for recreation and wildlife. Far from being a time consuming and costly burden on those charged with development and regeneration, adapting towns and cities to climate change offers enormous potential for creating high value, quality places where people and businesses will want to spend time.

As our communities change we can take opportunities to reduce our vulnerability and exposure to climate risks. With the appropriate policies in place, spatial planning and urban design can provide vital tools for ensuring that the UK is well adapted. The aim of Climate Change Adaptation by Design is to communicate the importance of adapting to some degree of inevitable climate change, and to show how adaptation can be integrated into the planning, design and development of new and existing communities.

Drawing on research just published as part of the Building Knowledge for a Changing Climate programme, the guide uniquely considers how adaptation options are influenced by geographical location and the scale of development. It considers the interrelated roles of the planning system, communities, other stakeholders and delivery bodies. It seeks to ensure a better understanding of climate risks while demonstrating effective adaptation strategies through case studies from around the world.

This is the third in the series of 'TCPA By Design Guides for Sustainable Communities'. The TCPA published its 'Programme for Sustainable Communities' in 2001 calling for the positive planning and delivery of a greater number of homes to higher standards in 'sustainable communities'. This demanded enhanced levels of biodiversity, renewable energy and energy efficiency. It set out a vision, which 'above all, sees our communities as integrated with the natural environment rather than set against it'. The following year the Government launched its groundbreaking Sustainable Communities Programme. This is the third in the series of TCPA By Design guides, which we hope will be of use to planners, urban designers, developers and to anyone engaged in creating sustainable communities.

**Robert Shaw**
TCPA Director (Policy & Projects)

# key messages

**1.** Adaptation is needed now because the climate is already changing. Many of the climatic changes forecast for the next 30–40 years are 'locked in'– the result of past greenhouse gas (GHG) emissions. Regardless of the success, or otherwise, of emissions reduction efforts, some climate change is therefore inevitable.

**2.** The built environment generally has a design life of 40–100 years, and the urban form has even greater longevity. This makes climate change a current, rather than a future issue. In order to help communities adapt, planners, urban designers, architects, and developers should take into account predicted climates over this century at the design stage of any new development, refurbishment or regeneration programme.

**3.** Climate change is a fast-moving policy area, and climate change adaptation is increasingly a requirement of national planning and design guidance.

**4.** Climate change presents designers, architects and planners with significant opportunities to create or remodel outdoor spaces and buildings that are resilient in the face of future climates. Adaptation will enhance the liveability of, and quality of life in, communities in future.

**5.** Climate change presents opportunities to develop new services and products that respond to changing customer preferences. The first to seize these opportunities can gain an 'early mover' competitive advantage.

**6.** Evidence of 'climate-proofing' can enhance an organisation's reputation with its stakeholders. Adaptation can also protect investments, reduce health risks, and reduce insurance costs.

**7.** Many adaptation strategies offer multiple benefits. As an example, managed realignment of hard flood defences (concrete or stone, for instance) can improve biodiversity as well as managing flood risks.

**8.** Planners, developers, architects and urban designers should aim to implement zero- and low-carbon adaptation strategies, in accordance with GHG emissions reduction targets. However, to be effective efforts to reduce emissions must take account of a changing climate and the need to adapt at the same time.

**9.** Adaptation is an essential component of truly 'sustainable development'.

# introduction

This section considers the climatic changes ahead, and the corresponding impacts on the built environment and urban form.

1

**Given the long lifetime and high cost of the built environment, it is imperative that we plan for and create communities that are robust in the face of climate change. New developments must be designed to cope with future rather than historical climates.**

The existing building stock, which is replaced at a rate of less than 1% yearly, presents a bigger challenge. Action is therefore needed to make existing communities more resilient to climate risks. The urban landscape, which includes open spaces and transport corridors, is even longer-lived and will need to cope with a changing climate over decades or even centuries. All of these elements will need to be 'remodelled' to deal with increasing temperatures, changing patterns of rainfall, and rising sea levels.

## The climate is changing

Up until now, efforts to address climate change have focussed primarily on reducing GHG emissions, by encouraging lower carbon lifestyles – the mitigation agenda. But this is only half the picture. The reality is that our climate is already changing, and we are experiencing the effects right now.

Even if we make significant reductions in GHG emissions today, we will need to cope with at least several decades of climate change, and centuries of sea level rise. The consequences of these changes can no longer be ignored. This is the other half of the picture – climate change adaptation.

Recently published research from the Building Knowledge for a Changing Climate (BKCC) programme[1] articulates a strong message of the urgency of adapting the built environment to climate change, but also of the opportunities that it presents.

Detailed information about the major climatic changes we can expect across the UK is available in the UKCIP02 climate change scenarios (www.ukcip.org.uk/scenarios) published by the UK Climate Impacts Programme[2], and in advice derived from them such as PPS25: Development and Flood Risk[3] and the draft supplement to PPS1 on climate change[4]. These scenarios should be used to assess and manage climate risks to all new and existing communities.

In 2008 UKCIP will publish a new set of scenarios (UKCIP08) with a web interface to deliver user-specified climate change information in a variety of formats. These scenarios will describe climate change in probabilistic terms, allowing a risk-based approach to decision-making for adaptation.

Headline future changes for the UK are outlined in the table below. These are assigned a relative level of confidence, based on the expert judgements of authors of the UKCIP02 climate change scenarios.

| Summary of expected climate change in the UK | | Confidence level |
|---|---|---|
| **Temperature** | • Annual warming by the end of the century of between 1°C and 5°C depending on emission scenario. | High |
| | • Greater summer warming in the southeast than in the northwest. | High |
| | • Increase in the number of very hot days. | High |
| | • Decrease in the number of very cold days. | High |
| **Precipitation** | • Generally wetter winters for the whole of the UK, and increases in winter precipitation intensity. | High |
| | • Substantially drier summers. | Medium |
| **Soil moisture** | • Decreases in summer and autumn, especially in the southeast. | High |
| **Sea level** | • Global average sea level will continue to rise for several centuries. According to the Intergovernmental Panel on Climate Change's 4th Assessment, global sea level will increase by the 2090s by between 20 and 60cm, depending on the emissions scenario (relative to the 1980–99 baseline)[5]. | High |
| | • There will be significant regional differences in relative sea level rise around the UK. | High |
| | • For some coastal locations and some scenarios, storm surges will become more frequent. | Medium |

What follows are synopses of the UKCIP02 climate change scenarios. The maps show changes in average annual or seasonal conditions, but cannot fully present local variation. Urban areas will be particularly vulnerable to extreme weather events (*see Figure 1*). The risks that these climatic changes present are described in section 4.

## Temperature

We are already experiencing the effects of a warming climate:

- Global average temperature has risen by about 0.6°C since the beginning of the twentieth century, with about 0.4°C of this warming occurring since the 1970s.
- The unusually hot summer of 2003 caused severe disruption and an estimated 2,000 excess deaths in the UK. Global climate models indicate that similarly hot summers could be normal within 30–40 years.
- The summer of 2006 was the longest continuous period of hot weather recorded in the UK. The heat wave had significant consequences for human comfort and health, and caused severe disruptions in London when soaring energy demand triggered blackouts.

The figure below shows projections across the UK. Patterns are presented for low and high GHG scenarios, for different seasons, and for three 30-year time slices: 2020s (near future), 2050s (mid century), and 2080s (end of this century). All changes are expressed with respect to the average 1961–90 climate, which itself incorporates some climate change.

**Weather extremes**

The climate scenarios do not fully present the extreme weather events to which urban areas are particularly vulnerable. The impacts are not just physical: there is also an important social dimension. We are already seeing increased frequency of events and climate change is expected to exacerbate this further. Recent events include:

- Very high temperatures caused by the Urban Heat Island (UHI) effect. The civil unrest in Paris during the summer of 2006 has been partly attributed to the prolonged heat wave.
- Severe storms, such as the one which caused huge damage to parts of southern England in 1987, may become more frequent.
- Flood events caused by long and heavy rainfall, such as recent events in Lewes and Carlise which both caused extensive and expensive losses to properties, will become more frequent.
- There is also concern amongst experts that the UK will experience more frequent damaging coastal storm surges and flooding. The impact on major population centres, such as London, could be catastrophic.

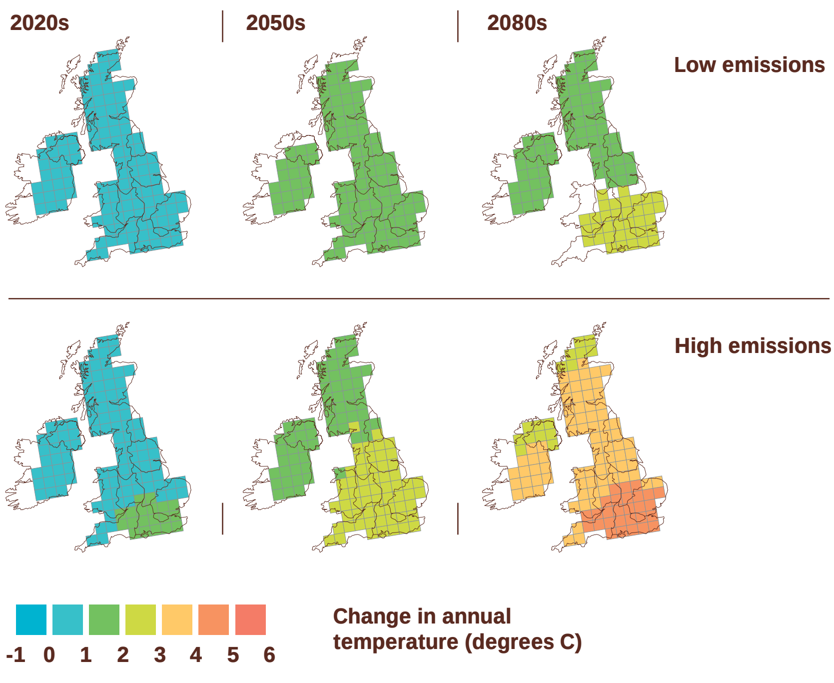



**Figure 1: Changes in average annual temperatures relative to the 1961–90 average, for the 2020s, 2050s and 2080s under the low (top) and high (bottom) emissions scenarios.** *Source: UKCIP02 Climate Change Scenarios.*

- Annual temperature increases of 4.5°C in the southeast by the end of this century under a high emissions scenario – the current difference between London and Barcelona is approximately 5°C.
- Pronounced warming in summer. Temperatures in south eastern urban areas will regularly reach 40°C by mid century.
- A distinct southeast-to-northwest gradient in the magnitude of warming. This will compound heat risks in areas that are already vulnerable.

The average changes presented above mask day-to-day variability and extremes, which will be more severe. In urban areas, buildings store heat and contribute to the Urban Heat Island (UHI) effect. The ASCCUE[6] project shows significant temperature differences between city centres and their surrounding countryside, but also surface temperature differences of up to 6°C between high and low density suburbs. These differences will become far more pronounced with climate change.

## Precipitation

The proportion of winter rainfall relative to summer precipitation across the UK has changed over time:

- Winters have never been as wet relative to summers in about 240 years of measurements as they have been over the last 30 years.
- The contribution of the most intense rainstorms to total winter precipitation has increased over the last 40 years. The proportion of winter precipitation falling in five-day or longer sequences of 'heavy' rain has also increased. Intense rainstorms increase the risk of severe flood events.
- In summer, the contribution of intense rainstorms to summer total rainfall has decreased. If this trend continues we can expect droughts similar to the one that affected the southeast in 2006 to become more common.

The scenarios show (*see Figure 2*):

- In the future, winter rainfall is expected to increase. In summer, the whole of the UK is expected to become drier, with rainfall decreases over England of 20–40% by the end of the century.
- Rising temperatures mean that significantly less precipitation will fall as snow. Reductions of 60% to 90% or greater (low to high emissions) can be expected by the end of the century.

Runoff of surface water is altered by urbanisation – hard surfaces increase the volume and rate of runoff.

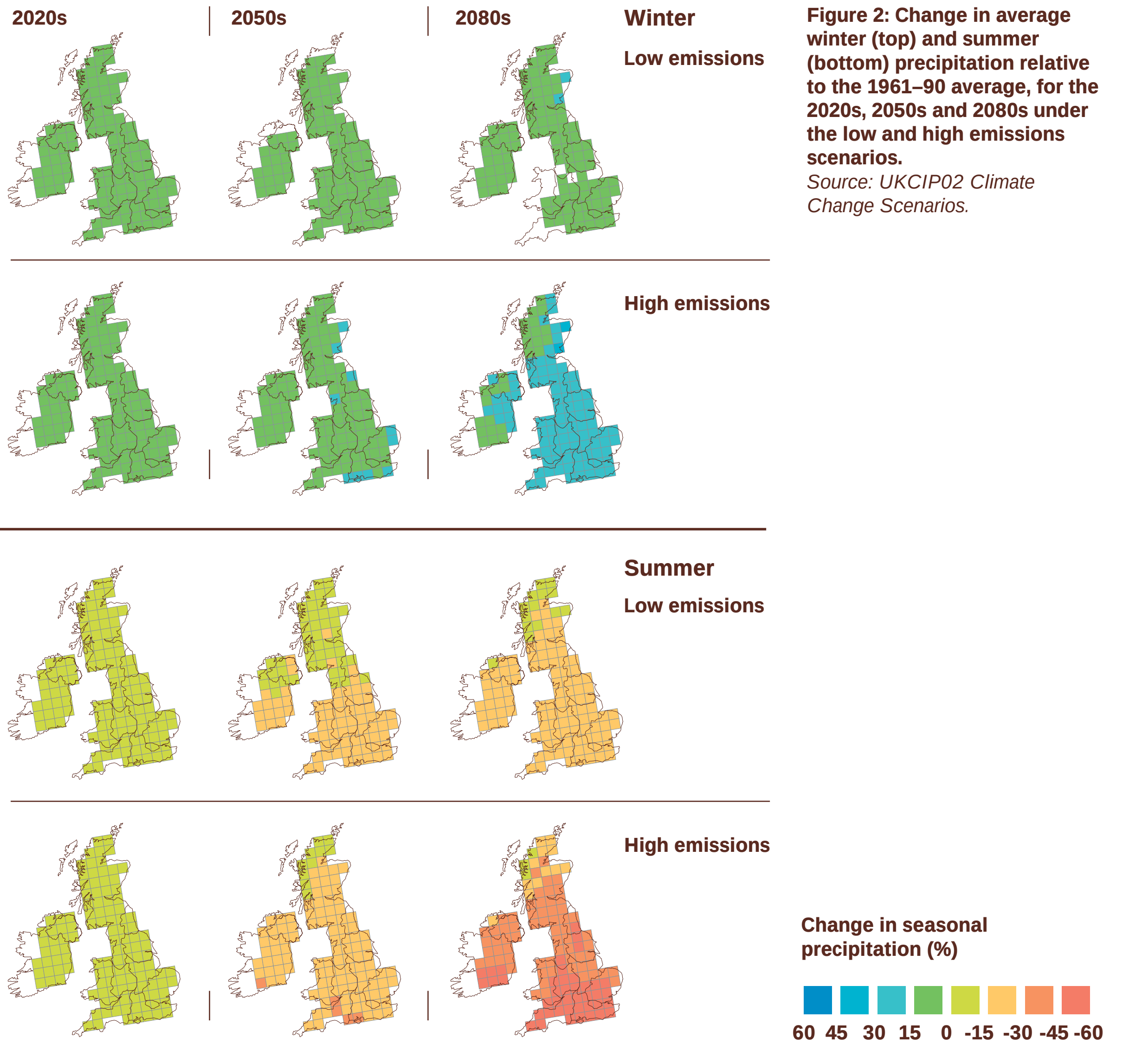



**Figure 2: Change in average winter (top) and summer (bottom) precipitation relative to the 1961–90 average, for the 2020s, 2050s and 2080s under the low and high emissions scenarios.**
*Source: UKCIP02 Climate Change Scenarios.*

## Soil moisture

Changes in soil moisture – important for flooding and ground stability – are shown in Figure 3.

## Sea level

Global average sea level rose by about 1.8mm/year between 1961 to 2003, increasing to about 3.1mm/year from 1993 to 2003. The increase is due to various factors, including thermal expansion of warming ocean waters and the melting of land-based glaciers. Future changes are likely to bring:

- Global average sea level rises of 0.2–0.6m by the 2090s according to the Intergovernmental Panel on Climate Change's 4th Assessment Report. New research suggests sea level rise may be even greater – a recent study projects a rise of 0.5–1.4m above the 1990 level by 2100[7].
- Greatest changes in the south and east of England, where the effects of mean sea level rise will be further exacerbated by subsiding land, following the last Ice Age.
- Increases in storm surge height and frequency, with serious implications for the standards of protection offered by coastal flood defences. This will affect many highly populated areas.

## Climate risks and opportunities

Climate change will affect different aspects of spatial planning and the built environment, including external building fabric, structural integrity, internal environments, service infrastructure (e.g. drainage, water, waste, energy, transport and telecommunications), open spaces, human comfort, and the way people use indoor and outdoor space. The BKCC programme has begun to quantify these impacts and develop tools to assist decision-makers make informed choices.

Some of the expected major risks and opportunities include:

- Significant opportunities for urban designers, architects and developers to create spaces and buildings that increase a community's resilience to climate change.
- Higher summer temperatures will have serious implications for human comfort, overheating and heat stress. *See BKCC[1] (pages 47–49) and ASCCUE[6].*
- Higher summer temperatures will lead to increased demand for cooling in buildings, particularly within high density areas where the UHI effect is most pronounced. But higher winter temperatures will decrease winter energy consumption.
- Hotter temperatures will lead to greater demand for urban greenspace, blue (water) infrastructure, open spaces and shading. *See ASCCUE[6] for more on this.*

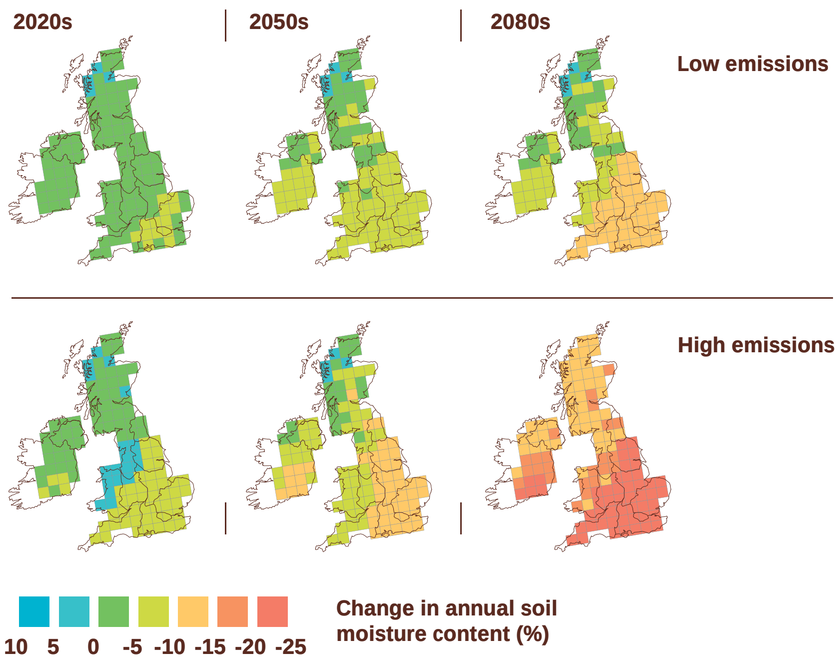



**Figure 3: Change in average annual soil moisture content relative to the 1961–90 average, for the 2020s, 2050s and 2080s under the low (top) and high (bottom) emissions scenarios.**
*Source: UKCIP02 Climate Change Scenarios.*

- The whole of the UK will experience a decrease in soil moisture annually. The highest reductions – 40% or more by the 2080s – will occur in summer under the high emissions scenario in southeast England.
- Winter will see a slight increase in moisture content over most of Scotland, and little change over Northern Ireland and Wales.
- Changes in autumn are similar to those in summer due to the long delay in restoring soil water levels following increasingly dry and hot summers.

- Greenspace and trees offer a way to cope with hot weather (through shading and evaporative cooling), but are themselves vulnerable to decreased water availability, rising temperatures, and changing patterns of disease and pests. *See ASCCUE[6] for more on this.*
- An obvious adjustment to hotter weather is to open windows and doors. This may result in knock-on impacts, such as greater risk of crime, noise and pollution. Innovative planning, design and technological solutions will be important for managing these risks.
- Changing patterns of precipitation will have significant implications for flood risk, water resources and availability, and water quality.
- Increased flooding of buildings and open spaces will lead to loss of life, injury, disease, mental stress, damage to buildings and their contents, contamination from sewage and access problems. Some properties may become uninsurable if they are in highly flood-prone areas.
- Increased precipitation intensity in winter will affect building facades and internal structures and lead to more rain penetration around openings.
- Subsidence and heave risks are expected to increase for clay soils, due to higher temperatures, lower summer rainfall, and increased evapotranspiration. Resulting impacts will affect properties and underground service infrastructure on subsidence-prone ground.
- Rising sea levels will present a significant challenge to flood risk management.
- Increased rates of coastal erosion, due to sea level rise and storm surges, as well as landslips on slopes and embankments can threaten buildings, land and infrastructure in vulnerable locations. *Refer to (section 4.4.1) for more on the climate impacts on slope stability.*
- More intense rainfall events will mean drainage systems (roof drainage, sewer systems, carriageway drainage etc) are unable to cope, resulting in flash flood events, especially in urban areas. *Refer to ASCCUE[1] and AUDIACIOUS (section 4.2.1) for more information.*
- The implications of climate change for the construction process are in some cases beneficial: fewer working days would be lost due to snow and frost, but workers will be more likely to suffer heat stress in summer.

**Learning lessons from vernacular architecture and design**

The vernacular architecture and urban form of other countries may offer lessons about responding to challenges imposed by climate change in the UK. Vernacular architecture is designed to suit local (historical) climates, and is a reflection of the customs and surrounding natural landscape of a community:

- inner courtyards that provide shaded open spaces
- circular house forms to combat strong winds
- stilt-supported buildings to minimise flood damage
- a mud roof that keeps out the heat of the sun.

Specific examples include the high, narrow streets of Marseilles which provide respite from the sun, the high thermal mass and fountain-filled courtyards of the Alhambra Palace in Spain, and the adobe pueblos of New Mexico.

Because vernacular architecture has evolved to be wholly suited to local conditions, it is not entirely transferable to other places. Even though future temperatures in the southern UK may resemble those of present-day southern France, many other factors (e.g. latitude, soil conditions) will contribute to a distinctive climate with individual challenges. Cultures also differ significantly from place to place, and this will influence the way people interact with buildings and urban environments.

Scale presents a further constraint to wholesale adoption of vernacular architecture. Domestic-scale measures, such as shutters or awnings, are transferable. Other, large-scale features, such as narrow tall streets are more difficult to implement in urban environments.

Vernacular architecture has always responded to the limits of the time and location. It provides a useful look at how other places and cultures have evolved to deal with the challenges of the current climate. These strategies may not be entirely appropriate for the UK, but they offer inspiration for adapting to a future climate.

# international and national context

This section describes the various policy and legislative drivers for adaptation action both internationally and in the UK.

2

**No single piece of legislation or policy covers action on climate change adaptation but this is a very fast-moving field, and several policy 'hooks' are already providing practical ways to reduce vulnerability to climate change.**

Climate change is now mainstream. It is no longer considered to be solely an environmental issue but one that will have serious economic and social repercussions. The Stern Review[8] of the economics of climate change called for urgent international action.

## International and European policy and legislation

Both the UN Framework Convention on Climate Change and the European Climate Change Programme cover adaptation to inevitable climate change in addition to emissions reductions.

Other key European legislation and policy directives, though not explicitly designed to tackle climate change, offer important means of addressing climate risks:

### Strategic Environmental Assessment (SEA) Directive

Under the EU SEA Directive (European Directive 2001/42/EC) planners are legally obliged to consider climate change when developing spatial plans. Climate change must be considered at various stages of the SEA process. There are two climate change issues to address – the impact/ constraints set by climate change on the plan, and the plan's effects on future GHG emissions. In the UK, the Sustainability Appraisal (SA) process is designed to fulfil the requirements of the SEA Directive.

*More info: www.ec.europa.eu/environment/eia*

### Water Framework Directive (WFD)

The EU WFD is an overarching programme to deliver long-term protection and improve the quality of groundwater, surface water and associated wetlands. Though the Directive does not currently require climate change to be taken into account, it will be implemented in planning cycles which allow consideration of long-term environmental trends, of which climate change is one.

*More info: www.ec.europa.eu/environment/water*

## National policy and legislation

The UK Climate Change Programme details the policies and measures which the UK is using to cut GHG emissions and adapt to the impacts of climate change. It recognises that planning has a crucial role to play in improving the adaptive capacity of development. Current government planning policy in England advises that, used positively, spatial planning has a pivotal role in helping[4]:

- Secure enduring progress against the UK's emissions targets.
- Deliver zero carbon development.
- Shape sustainable communities that are resilient to climate change.
- Create an attractive environment for innovation and investment in renewable and low-carbon technologies and infrastructure.
- Give local communities opportunities to influence, and take, action on climate change.

In addition, the following specific policy and legislation can help manage climate risks:

- Building regulations require increased energy efficiency, but future regulations will also increase buildings' resilience to climate change.
- The Government's Code for Sustainable Homes aims to increase the environmental performance of homes, above building regulations. Compliance will improve water efficiency and management of surface water run-off in new homes.
- The Government is developing an Adaptation Policy Framework (APF). It will identify the roles of central government departments and devolved administrations and aims to provide the structure for developing adaptation strategies and policies by all organisations.
- Areas of major change, such as regeneration and growth in the Government's Sustainable Communities Plan, offer important opportunities to incorporate climate change adaptation. Similarly, major refurbishments which fall under the planning system are subject to the same controls and mechanisms that guide new development. *www.communities.gov.uk*
- Public sector land and property owners have a significant opportunity to establish property investment policies which require adaptation.
- The Civil Contingencies Act sets out roles and responsibilities of those involved in planning for civil emergencies, including natural disasters caused by climate change. *www.ukresilience.info*

# delivering adaptation action

**This section proposes a framework for delivering adaptation action at the regional and local levels, together with some guidance on creating local adaptation strategies.**

# 3

**Adaptation helps ensure that our urban environments are more robust in the face of inevitable climate change, but it offers other opportunities as well. By building adaptive capacity and delivering sound adaptation solutions we can also make cities more attractive, with a better quality of life. Effective adaptation in the built environment needs to be supported by robust policy and a range of incentives to ensure delivery on the ground.**

This section describes key guiding principles and specific mechanisms by which regions and local authorities can deliver climate change adaptation. It also provides examples of existing or draft strategies that have been developed in the UK which address adaptation.

## Key climate adaptation principles

**Seek opportunities to incorporate adaptation into new and existing developments**
Planners, designers and developers should work together to ensure that any new development (or regeneration) takes account of climate change impacts. They have many ways of facilitating adaptation. While it is often more cost-effective to adapt new developments at the planning and design stages, regeneration efforts also offer significant opportunities to incorporate adaptation.

**Work in partnership with communities**
Engagement with local communities is crucial to developing adaptation actions that will work best on the ground. Partnership working with households and the public and private sectors should form a fundamental part of the process of developing climate change adaptation strategies from the outset.

**Incorporate flexibility to deal with changing risks**
Adaptation efforts must incorporate sufficient flexibility to deal with changing climate risks over time. The most appropriate responses will differ depending on the scale at which they operate – from conurbation, to neighbourhood, to building scales.

**Understand existing vulnerabilities to climate and identify critical thresholds**
The imperative for adaptation is greatest in areas that are already vulnerable to climate risks. Understanding how the weather currently affects an area and identifying critical thresholds – such as the maximum rainfall capacity of a storm-sewer system – can help determine when and what adaptation actions to undertake.

**Identify key climate change risks using the latest climate change scenarios**
Knowledge about climate change is evolving fast. The latest scenarios for the UK are provided by the UK Climate Impacts Programme.

**Look for no regrets, low regrets, win-win and adaptable measures to manage climate risks**
Some policies and measures are particularly useful for managing the uncertainties inherent in climate change, including:

- No-regrets – those that will pay off immediately under current climate conditions.
- Low-regrets – low-cost policies and measures that have potentially large benefits. These should be identified as early as possible in the design process, to maximise opportunities and minimise costs.
- Win-wins – policies and measures that help manage several climate risks at once, or that also bring other benefits, such as complementary reduction in GHG emissions.
- Adaptable, flexible and resilient policies and measures, so places can adapt to a continually changing climate.

**Adopt a sequential and risk-based approach to development decisions**
When allocating land in development plans or deciding applications for development, decision-makers should demonstrate that there are no reasonable options available in a lower-risk category, consistent with other sustainable development objectives.

**Avoid actions that will make it more difficult to cope with climate risks in the future**
These are called adaptation constraining decisions. One example is inappropriate development in a flood risk area.

**Review your adaptation strategy regularly**
Adaptation strategies must be kept under regular review, keeping abreast of new knowledge about climate change and learning from experience.

Regardless of location, scale or development type, the overall approach to climate change adaptation should be based upon the guiding principles shown previously (adapted from UKCIP and other guidance[9]). In practice, adaptation strategies must take into account public attitudes, physical location, design life, attitudes to risk, surrounding

## How regions can deliver climate change adaptation

Because spatial planning takes account of the impact of future climate change, it provides a key mechanism for delivering adaptation. Regions have an important role to play. In England and guided by national policy, Regional Spatial Strategies (RSS) provide the strategic element of a development plan and inform preparation of Local Development Frameworks (LDF). RSS (and LDF) require an assessment of climate risks through the Sustainability Appraisal (SA) process. The box on the previous page shows how adaptation is being integrated into regional planning in southwest England and London.

Formal climate change partnerships are active in all regions of England and in the Devolved Administrations, working under the umbrella of UKCIP. The partnerships raise awareness of the regional impacts of climate change, develop examples of practical adaptation responses, commission research, and press for management of climate risks within regional strategies and plans.

# case studies

### Adaptation through regional planning: Regional Spatial Strategy for Southwest England

The draft RSS takes account of climate change and the increasing risk of coastal and river flooding. In order to manage these risks the strategy recommends relocation of existing development from at-risk coastal areas and identification of areas for managed realignment. This will also create new wildlife areas.

The strategy also recognises that new development is vulnerable to climate risks unless water resources are sustainably managed. The document advises local authorities to consider water resources as an element of sustainable construction, so requiring the introduction of water conservation measures and sustainable drainage systems in all development through supplementary planning guidance.

*More info: www.southwesteip.co.uk*

### Climate Change Adaptation Strategy, Greater London Authority

The Mayor of London is preparing a Climate Change Adaptation Strategy for London, the first for a world city. The adaptation strategy will provide strong policy directions on flood risk, water resources and managing UHI effects. It will feed into the review of the London Plan. The Mayor has also published Supplementary Planning Guidance on Sustainable Design and Construction, which includes detailed advice on addressing climate adaptation.

*More info: www.london.gov.uk/mayor/environment/strategy.jsp*

## How local areas can deliver climate adaptation

Local government has a pivotal role in achieving sustainable development including mitigating and adapting to climate change. The following steps will guide local authorities in preparing a framework for adaptation that includes a policy vision and incentives for change:

- Local authorities should make a public, high-level commitment to tackling climate change, such as signing the Nottingham Declaration on Climate Change. This high-level statement of commitment should recognise the need for concrete action by setting measurable targets. It can then be used to guide policy and create a context for corporate and community action.
- Cross-cutting issues can then be addressed through the Local Strategic Partnership (LSP), or Community Strategic Partnerships (CSP) in Wales. LSPs and CSPs bring together the public, voluntary, community and private sectors to co-ordinate the contribution that each can make to improve local areas. Underpinning and supporting the LSP are various thematic partnerships responsible for tackling specific agendas, including adaptation to climate change.
- Local authorities and their strategic partners have responsibility for drawing up a Sustainable Community Strategy (SCS).[10] The Strategy provides the overarching framework for delivering climate change adaptation and mitigation.

LSPs, SCSs, Local Area Agreements (LAAs), and local public service agreements offer local authorities new opportunities to set and achieve a vision for their areas with their partners. They allow different agencies to pool budgets in pursuit of common aims and challenging targets. These local partnerships can be a key vehicle for climate change adaptation.

# case studies

### Tools for local authorities – Nottingham Declaration Action Pack (NDAP)

More than 200 authorities have already signed the Nottingham Declaration, which commits signatory authorities to addressing the causes and impacts of climate change according to local priorities. The Nottingham Declaration Action Pack (NDAP) is an online support tool designed to help local authorities to address the challenges of climate change.

*More info: www.est.org.uk/housingbuildings/localauthorities/NottinghamDeclaration*

### LDF and Sustainability Appraisal, City of London

The City of London has developed an adaptation strategy to ensure that the City's services and infrastructure continue to function appropriately in the face of climate change. One of the routes for delivering this adaptation strategy is the City of London's LDF. By incorporating a Sustainability Appraisal (SA) process, which obliges planners to take account of climate change when developing spatial plans, the City of London demonstrates how planning policy can help to manage climate change risks.

*More info: www.cityoflondon.gov.uk/Corporation/living_environment/sustainability/climate_change*

Planning is another important delivery mechanism for the local authority's vision. LDFs in England and Local Development Plans (LDPs) in Wales provide the spatial expression of each SCS, therefore the strategy should point to practical actions which can be addressed through planning. All plans that form part of LDFs should be climate-proofed through SA.

In England, the following can be used to implement climate change adaptation through the LDF:

- Policies in Core Strategies and Local Development Documents (LDD) can support RSS policies by requiring action on climate change.
- Area Action Plans (AAPs) can help identify areas or properties that are at risk from flooding or other hazards *(see ASCCUE[6])*. AAPs can also complement Core Strategies where significant change is proposed by providing policies relating specifically to the developments proposed.
- Supplementary Planning Documents (SPD, or Supplementary Planning Guidance in London) can provide more detailed guidance on adaptation. Topic-based SPDs offer local planning authorities the opportunity to provide specific guidance and advice to developers in relation to managing climate risks. In the Planning Response to Climate Change[11], the Government suggests that a climate-sensitive development checklist could be incorporated into SPDs on sustainable development or sustainable design and construction. *See the Three Regions Climate Change Group[12] checklist.*
- Legally, the attachment of planning conditions and obligations is an effective way of controlling local development (e.g. by requiring SUDS to manage pollution and flood risk). Planning obligations, sometimes called 'Section 106 agreements' or planning gain, can act as a key instrument for enabling developers to contribute to climate proofing by requiring them to minimise future impacts and to carry out works which will provide community benefits.

Policy on climate change adaptation is evolving quickly. Below is a 'forward look' towards potential future policy directions.

# future policy directions

### Identifying areas of water stress: Water Saving Group

A Water Saving Group (WSG), which includes government departments, regulators, water companies and consumer organisations, is developing a method of identifying areas of England that have different levels of water stress. By classifying areas in this way the group can focus activities aimed at saving water in those areas where there is greatest need and greatest potential benefit. This methodology goes beyond indicative water resource maps, and may be used by planners to define regional or local water efficiency standards in spatial plans.

*More info: Consultation open at www.environment-agency.gov.uk*

### Integrated Water Strategy: Ashford

The Environment Agency has carried out an integrated water management study to assess the constraints to growth in Ashford that might arise in relation to meeting demand for potable water, the impact of treated effluent on receiving waters, and management of flood risk. This takes account of the impact of climate change on both demand for, and availability of, water resources.

*More info: www.environment-agency.gov.uk*

# how to implement adaptation through design and development

This section illustrates a menu of adaptation options using practical examples and organised according to the main climate risks that communities in the UK will face at different spatial scales (conurbation or catchment; neighbourhood; and building scales):

4.1 Managing high temperatures

4.2 Managing flood risks

4.3 Managing water resources and water quality

4.4 Managing ground conditions

# 4

**Our cities are not currently designed for climate change. It presents planners and designers with significant challenges, but also enormous opportunities to create innovative urban environments that will be attractive while functioning well as the climate changes. Architects and developers must also think creatively, to ensure that the built environment adapts to the changes ahead.**

Many adaptation strategies contribute to wider policy objectives and the creation of a quality public realm. The imperative to manage high temperatures and reduce flood and drought impacts can justify the creation and maintenance of green infrastructure. In turn, a linked network of open spaces that can be used by a range of people contributes to quality of life and health. It also has a crucial role in maintaining and improving air quality, flood and surface water management and biodiversity[13].

Climate change mitigation and adaptation are strongly influenced by urban form. At high densities, travel distances are minimised and community energy schemes become more viable, with obvious advantages for emissions reduction. However, higher densities can conflict with adaptation objectives by intensifying UHI effects and reducing urban drainage capacity.

An adapted and sustainable urban environment makes use of well designed green and blue spaces for cooling, water storage capacity, and infiltration of rainfall. Unfortunately, greenspace, be it public or private, is often sacrificed in the course of urban development. Poorly adapted cities that are not designed to cope with hotter, drier summers will require increased use of mechanical air conditioning. This not only contributes further to climate change, but has social implications too. Planners, developers, urban designers and architects must consider the potential conflicts between adaptation and mitigation responses in order to ensure sustainability of future communities *(See McEvoy et al, 2006[14])*.

The case studies presented in the following sections illustrate adaptation strategies to manage a range of climate risks at three spatial scales. These offer transferable lessons, but adaptation strategies will need to respond to local socio-economic circumstances and built form.

### Conurbation or catchment scale

Climate change adaptation at this scale will potentially serve the whole city and is likely to include a variety of land uses. Opportunities for creating cost-effective and integrated solutions as part of an overarching climate change strategy (perhaps embedded within an RSS, Community Strategy, Open Space Strategy or LDF) may be greatest at this scale.

### Neighbourhood scale

This scale involves developments of discrete groups of dwellings, including a mix of uses, and can vary in size from an individual block to a large estate. Consideration will need to be given to adapting the public realm and spaces between buildings and developments. Solutions can be developed through an LDF, Open Space Strategy, AAP, site brief or masterplan.

### Building scale

Smaller developments including individual dwellings, apartment blocks or commercial buildings provide opportunities for integrating climate change adaptation into or around buildings. Attention will need to be given to the design of the building, its surroundings, and how it is used and managed, in order to maximise current and future climate adaptation potential. Design or building codes provide useful tools.

While climate change adaptation presents opportunities, potential conflicts exist between different objectives. Narrow, tall streets can reduce heat risks during hot summers, but they may also aggravate winter gloom. Buildings designed to minimise energy use for winter heating may be susceptible to overheating problems in the summer if future climate is not taken into account.

Adaptation decisions will be influenced by location. It is important to recognise the relationship between large-scale strategic adaptation strategies at the conurbation scale (e.g. networks of open spaces) and smaller scale options (e.g. orientation of individual buildings). Higher densities in urban areas will exacerbate some climatic risks (e.g. thermal discomfort, health and urban flash flooding), but these risks will also create opportunities by highlighting the need for development of high quality green spaces and innovative use of layout and urban form. Suburban areas characterised by lower densities offer more versatile spaces for developing adaptation solutions. Rural-urban fringes, where densities are likely to be low, provide space for large-scale strategies such as strategic green space infrastructure and flood storage.

# 4.1 managing high temperatures

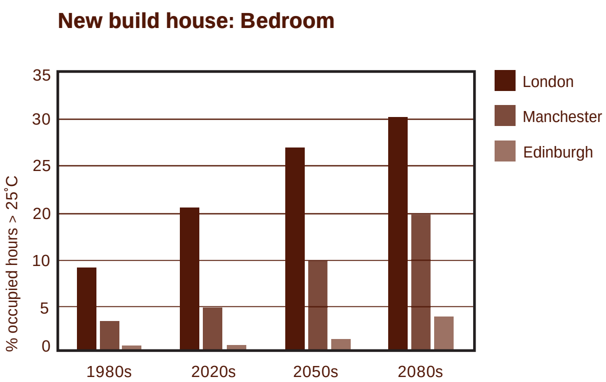
**The UK has not traditionally been preoccupied with the risk of overheating, but the hot summers of 2003 and 2006 showed that sustained high temperatures have significant impacts. This section illustrates the variety of strategies available for managing high temperatures from the conurbation scale, to counteract the urban heat island UHI effect, to structural adaptation at the building scale.**

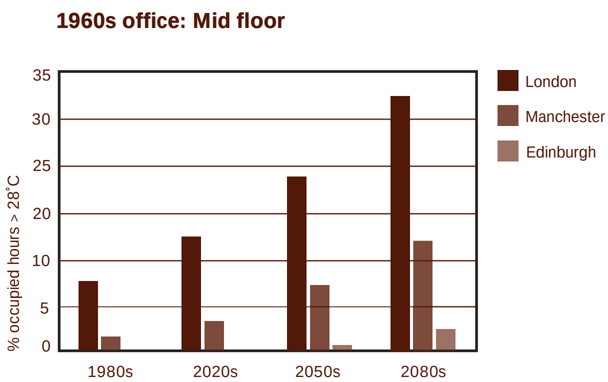
Climate change offers opportunities to provide greater outdoor amenity in view of longer periods of warmer weather. Access to evening and night-time open spaces, especially in high density areas, will become increasingly important.

**Where is the imperative for adaptation greatest?**
Current climates differ across the UK and will vary further under climate change. The imperative for adaptation to heat risk is greatest in the south and east, where temperatures are currently warmest and where the largest temperature rises will occur; the UHI will significantly amplify this risk in cities. The adaptive capacity of different communities also varies. Vulnerable groups, such as elderly inner city residents in poor quality housing will be disproportionately affected.

Figure 4 compares the percentage of hours that a 'hot' discomfort temperature (25°C for a bedroom in a new build house, and 28°C for a 1960s office) is exceeded for three cities, taking account of the climate change scenarios described in Section 1. Buildings are said to have overheated if these temperatures are exceeded more than 5% of the time. As shown, Edinburgh is not exposed to overheating risks until the 2080s, whereas London is already experiencing problems.

**Figure 4: The percentage of hours that the 'hot' discomfort temperature is exceeded in two different buildings due to climate change.**
*Source: Beating the Heat: Keeping UK buildings cool in a warming climate. UKCIP Briefing Report (2005).*

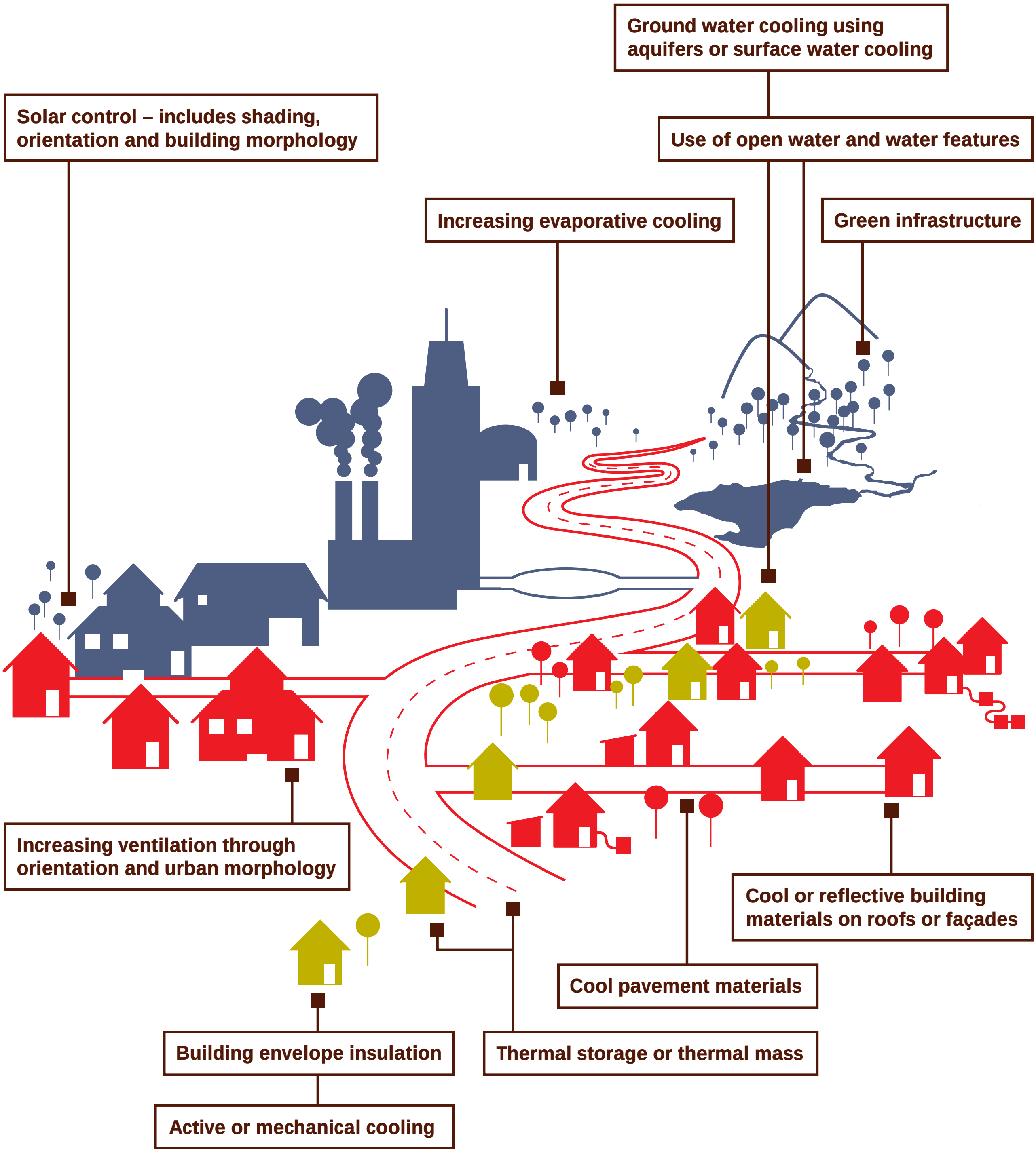


# menu of strategies for managing high temperatures

The diagram summarises the range of actions and techniques available to increase adaptive capacity. Detail is given in the text on the proceeding pages.

| Key | |
|---|---|
| (dark blue) | Conurbation/catchment scale |
| (red) | Neighbourhood scale |
| (olive) | Building scale |



## 4.1.1 managing high temperatures at the conurbation scale

At this scale, efforts to manage high temperatures should focus on the opportunities for reducing UHI effects through large scale infrastructure. Adaptation should be built into other broad, conurbation scale changes, and multiple benefits should be sought for biodiversity, recreation and flood management objectives.

As with efforts to reduce GHG emissions, developers, architects, planners and urban designers will need a shared vision and new approaches to design, funding and management. Project teams should work with planners to create a masterplan, concept statement or AAP for development. Adaptation should be considered from the outset, not added as an afterthought.

Built environment professionals should aim for integration of water, open space and built form through greenspace and bluespace strategies, developed as part of a masterplan. This should consider a number of climate risk management options (bearing in mind the potential conflicts between options and with GHG mitigation efforts), including:

- High quality greenspace, made up of a linked network of well-irrigated open spaces that can be used by a range of people (a 'green grid'), which has additional ecological, recreational and flood storage benefits. Green infrastructure in urban areas includes open spaces, woodlands, street trees, fields, parks, outdoor sports facilities, community gardens, village greens, private gardens, and green or living roofs and walls. It will also be important to consider subsidence risk, availability of water, longer growing seasons and changing species suitability under climate change.
- Bluespace, such as open bodies of water, including rivers, lakes and urban canals.
- Shading and orientation to reduce excessive solar gain (e.g. through narrow streets or canopies of street trees). Efforts to maximise shade in summer will need to take account of the need for light and warmth in winter.
- Passive ventilation captured through orientation and morphology of buildings and streets. Again, efforts to catch breezes and increase canyon ventilation paths must also consider the need for winter warmth.

## case studies

### ASCCUE project tools

The Adaptation Strategies for Climate Change in the Urban Environment (ASCCUE) project is the first to quantify the potential for green infrastructure to moderate climate change impacts in urban areas. Developed with national and local stakeholders, the study produced a conurbation scale risk and adaptation assessment methodology to support the development of climate change policy. This tool allows a large urban area to be screened as a prelude to neighbourhood scale analysis. It provides a broad view of the whole urban system, considering both macro and micro scale adaptation.

*More info: Gwilliam et al[16] and www.k4cc.org/bkcc/asccue*

### Chicago Wilderness

Developed as ecological conservation areas, Chicago Wilderness is a mosaic of urban forests embedded in one of North America's largest metropolitan regions. It includes more than 102,000 ha of land and water. The greenspaces not only reduce UHI effects, they also help purify city air, reduce heating bills through windbreak trees, absorb storm water runoff, and lower noise pollution. As it is supported by 190 member organisations from government, business, and the voluntary sector, Chicago Wilderness serves as a powerful model for a collaborative approach to urban forestry.

*More info: www.chicagowilderness.org/*

### Roof Gardens, Tokyo

Tokyo has suffered a rapidly worsening UHI effect since the 1960s, caused by increasing urban energy consumption and spread of non-porous ground cover (e.g. asphalt, concrete and buildings). To counteract this effect, Tokyo Metropolitan Government (TMG) has implemented several urban greening policies, including measures to encourage roof gardens.

All new developments with a ground surface of at least 1000m$^2$ (250m$^2$ for public buildings) must be equipped with green roofs and living wall surfaces. Policies extend to existing buildings as well as new developments. A tax reduction is offered on buildings with roof gardens, and the Development Bank of Japan offers low-interest loans to building owners who plan roof gardens.

*More info: www.toshiseibi.metro.tokyo.jp/plan/pl_index-e.html*

## 4.1.2 managing high temperatures at the neighbourhood scale

At the neighbourhood scale, efforts to manage high temperatures should focus on providing cool and attractive outdoor areas. If well designed, adaptation at this scale can also benefit internal spaces (e.g. street trees provide evapotranspirative cooling outdoors, as well as shading buildings).

Effective adaptation of the public realm will make use of bioclimatic design principles, taking account of climate and environmental conditions to maximise comfort and efficiency. Design codes can provide a useful tool for managing conflicts and ensuring a development's compliance with the overall concept of resilience to future climate. The key adaptation measures are:

- Evaporative cooling effects from a matrix of green corridors, smaller open spaces, street trees, and green or living roofs and walls. The ASCCUE project shows that a 10% decrease in urban green results in increased maximum surface temperatures in Manchester of up to 8.2°C by the 2080s under a high emissions scenario. But, a 10% increase will keep temperatures at or below current temperatures up until the 2080s. Green roofs have a similar effect. Planning for greenspace will need to take account of changing patterns of precipitation and availability of water.
- Increased use of ponds, roadside swales, flood balancing lakes, swimming pools and fountains.
- Orientation of buildings and streets to reduce excessive solar gain and catch breezes.
- Cool pavement materials on roadways or large parking areas – to increase surface reflectivity (though it is important to avoid glare problems) or increase rainfall permeability to benefit from the cooling effect of evaporation. Porous cool pavements offer the additional benefit of rainwater infiltration at times of heavy rain.
- Networks of 'cool roofs' made of light coloured materials to prevent solar heat gain and reduce the need for mechanical cooling.

## case studies

### Stratford City redevelopment

Redevelopment of the Stratford City brownfield site incorporates passive systems and design solutions where possible to provide comfortable working and living environments. The detailed master planning of Stratford City aims to create a comfortable, safe microclimate that contributes to delivering successful outdoor spaces. The development's Site-wide Strategy for Microclimate recognises the need to counteract the UHI using, for example:

- façade materials that absorb less solar heat
- plants in open areas to provide shade
- open water features to cool the air.

*More info: www.futurestratford.com*

### Frankfurter Strasse, Hennef, Germany

The town of Hennef has implemented a number of strategies to improve its main roads, including greening up the street environment, pavement widening, and making good use of street furniture. This has created pockets of well-designed public space with trees forming avenues or buffers. Though this scheme was designed primarily to create a safer environment and reverse the economic decline of the town's main street, the greenery provides comfortable outdoor spaces in the face of rising temperatures. Frankfurter Strasse is now a thriving high street.

*More info: www.newlifeformainroads.org.uk/*

Stratford City redevelopment
*Source: Arup Associates*

Frankfurter Strasse, Henef, Germany
*Source: Transport 2000 / Axel C Springfield*

**Sunshine Coast University, Australia**

This university campus is laid out in a linear arrangement of open and built space, with a long axis orientated to allow buildings optimum solar gain in winter and cooling sea breezes in summer. Heat risk management strategies on this campus include:

- Central courtyards of semi-open shaded spaces which provide 'cool pools' for cross ventilation into adjacent spaces. The temperature of air drawn into the courtyards is maintained or cooled by each courtyard's mass, vegetation and absence of solar gain.
- Bio-climatic 'weather walls', equipped with louvres and sliding windows, which provide a shaded space of one metre width outside exterior walls.
- Thermal chimney vents and louvres to move warm air away from working and living spaces.
- Extensive use of screens, fins, sun shelters and tree plantings to reduce direct sunlight on buildings.

*More info: www.csdesign.epsa.uq.edu.au*

# 4.1.3 managing high temperatures at the building scale

At the building scale it will be important to avoid maladapted design, where energy efficiency measures (e.g. to increase solar gain and reduce winter heat loss) have the potential to exacerbate summer heat risks. While mechanical air conditioning is an obvious way to guarantee thermal comfort during hotter summers, this solution would contribute excess heat to the surrounding air, significantly increase energy demand and compromise GHG reduction targets. Emerging best practice is to reduce cooling load as far as possible using passive solutions and then find the best mechanical solution to meet any remaining cooling requirement using the option that best fits the other design objectives.

A number of structural solutions offer effective means of managing heat risks and reducing thermal discomfort at this scale, including:

- Planting, shading and advanced glazing systems to reduce solar heat gain *(see Bratislava image below)*.
- Materials to prevent penetration of heat, including use of cool building materials and green roofs and walls.
- Innovative use of water for cooling, including ground water cooling using aquifers or surface water (possibly as part of SUDS).
- Mechanical cooling, including chilled beams and conventional air conditioning systems.
- Increasing ventilation and removing heat using fresh air (only effective when outside air is cool).
- Use of thermal storage or mass to absorb heat during hot periods so that it can dissipate in cooler periods, usually using ventilation. Ground coupled systems make use of thermal storage in the ground.

Trees reducing the need for air conditioning, Bratislava
*Source: John Handley*

Adnams Brewery Warehouse, Suffolk
*Source: Lime Technology*

# case studies

## Adnams Brewery Warehouse, Suffolk

This low-rise building is designed to eliminate the need for summer cooling and winter heating. It is constructed of hemp and chalk blocks which help to regulate temperature naturally and efficiently. The thick, porous walls help the building to act like a cellar, maintaining an even ambient temperature throughout the year. The thick warehouse walls have a cavity wall constructed of two skins of blocks, which are filled with a hemp-lime mix. Very little energy is required to produce the materials and build the walls, and the hemp acts as an extremely good insulator. It also allows the walls to 'breathe', keeping damp at bay.

Several other innovative design strategies have been incorporated to reduce need for cooling:

- An internal door system has been designed to create an insulation tunnel that maintains the warehouse temperature at a constant 11°C, reducing the need for refrigeration units.
- Roof beams overhang each side of the building, offering shading and helping to maintain a cool internal temperature.

*More info: www.newbuilder.co.uk/news/ > Adnams*

## Council House 2, Melbourne, Australia

The design of the 10-storey Council House 2 (CH2) office building incorporates dark-coloured air extraction ducts that absorb heat from the sun, helping air inside rise up and out of the building. The south façade has light-coloured ducts that draw fresh air in from the roof.

Outside air from a night purge (natural night-time ventilation) cools thick concrete ceilings that store this coolth due to their high thermal mass. This coolth then radiates back into the office space during the day. A separate water stream passes through chilled ceiling panels and beams to further cool the building.

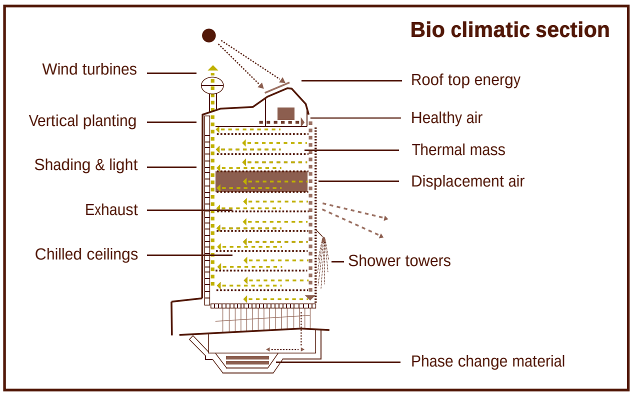
CH2 occupants are able to control the flow of incoming fresh air to work spaces via floor vents, and louvres move according to the position of the sun to provide shade. Finally, vertical planting on the north façade filters strong sunlight and provides additional shade.

*More info: www.melbourne.vic.gov.au*

## Menara Mesiniaga, Subang Jaya, Malaysia

This 15-storey building incorporates a number of innovative strategies to manage heat risks. The façade contains deep balconies which are planted to provide shade and evaporative cooling. Circular floors of office space with triple-height recessed terraces are also planted. These atriums enable cool air to flow through the building's public spaces while the planting provides shade. Windows facing the sun are equipped with aluminium fins and louvres to reduce solar heat gain and provide shading. All of these features, combined with a sunroof which incorporates solar panels, reduce long-term maintenance costs and contribute to lower energy usage.

*More info: www.ellipsis.com/yeang/*




Adapted from Council House 2, Melbourne, Australia
*Source: Corporate Communications City of Melbourne*

Menara Mesiniaga IBM Headquarters. *Source: Ken Yeang at T. R. Hamzah & Yeang Sdn.Bhd. Photography by K. L. Ng Photography*

# 4.2 managing flood risks

**Rising sea levels, increases in average winter precipitation and in the frequency, duration and intensity of heavy downpours will increase flood risks. Impervious surfaces in urban areas will exacerbate the risks by preventing rainwater from percolating into the ground.**

Changes in the catchment, such as field drainage and channelisation of water courses adds to the problem. Areas where drainage capacity cannot cope with current levels of precipitation will be at greatest risk.

Flood risk management measures should provide added health, ecology and leisure benefits by enhancing the quality of public space.

The most effective way to manage future flood risks is to reduce exposure. This involves assessing risk over the life of a development and locating and designing developments accordingly. The approach, outlined below, can be applied at all levels of planning and design and is described in detail in PPS25 (Development and flood risk)[17] and the associated Practice Guide:

**Assess risks**
- Identify land at risk and the degree of risk of flooding from river, sea and other sources.
- Prepare assessments of flood risks that contribute to SA / SEA.

**Manage risks**
- Direct development, particularly for vulnerable uses, away from flood risk areas.
- Manage any residual risks, taking account of climate change over a development's lifetime.

**Reduce risks**
- Safeguard land that is required for current and future flood risk management.
- Reduce flood risks to and from new development through location, layout and flood resilient design.
- Use sustainable drainage systems (SUDS).
- Make space for water – use green infrastructure for flood storage, conveyance and SUDS, re-create functional floodplains.
- Take opportunities to relocate existing buildings that will be vulnerable to flooding.

**Take a partnership approach**
- Work with stakeholders, such as the Environment Agency and Scottish Environment Protection Agency.
- Ensure spatial planning supports flood risk, river basin and surface water management policies and plans, and emergency plans.

Implementation of the Water Framework Directive in the UK brings opportunities for Integrated Water Resources Management (IWRM). IWRM calls for holistic consideration of the total watershed, including surface and ground water, quantity and quality issues, ecology, the relationship between land and water resources, and the different socio-economic functions of the watershed.[18]

Some of the adaptation options for managing flood risks also function as effective strategies for water resources and quality management. These risks are dealt with in 4.3. Given that climate change will result in heavier winter rainfall and drier summers a more coordinated approach to flood risk, water resource and water quality management would offer significant benefits. Similarly, upland planting can reduce soil erosion, and green roofs can help to manage high temperatures in buildings.

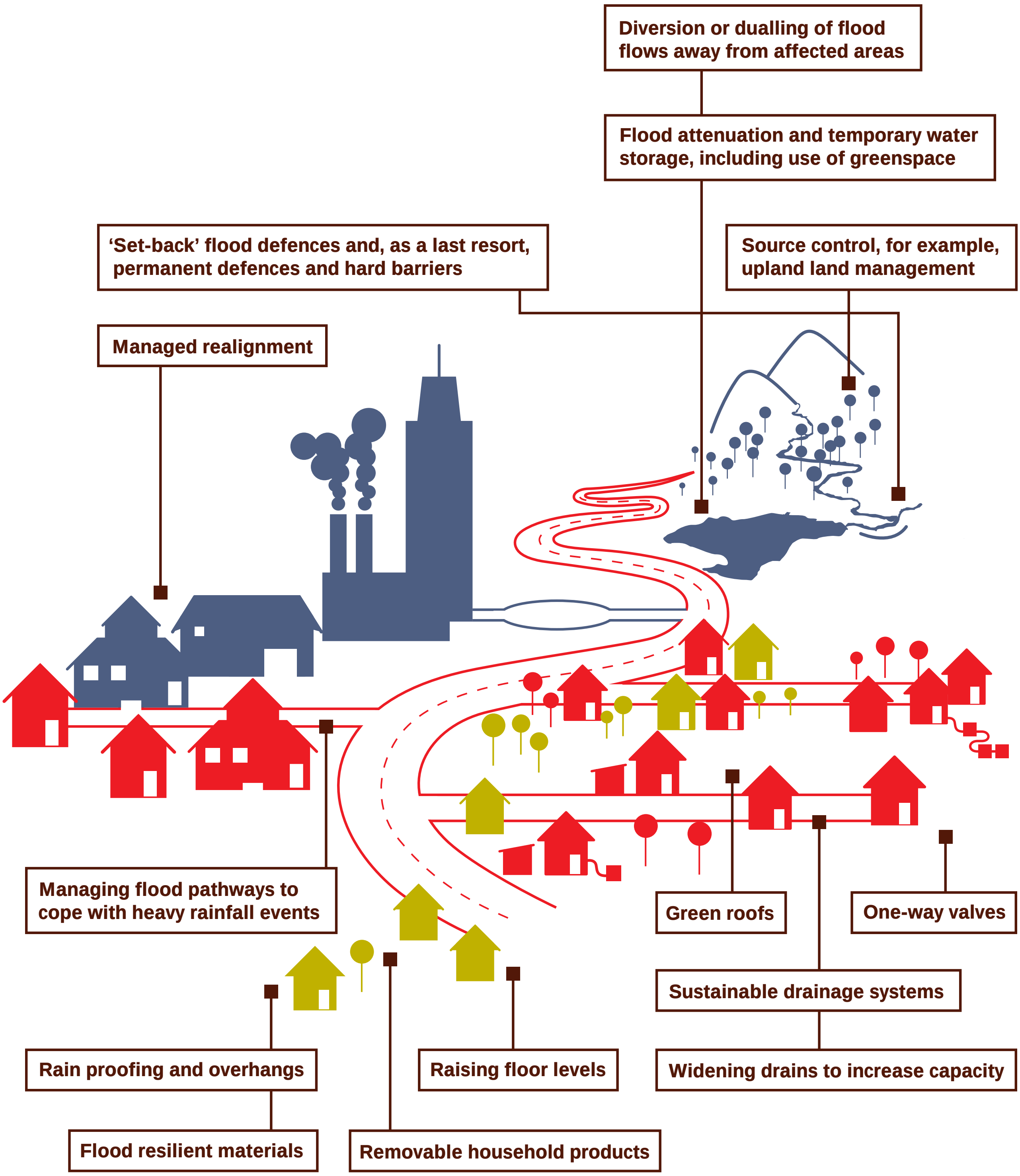
**Where is the imperative for adaptation greatest?**
Risks from tidal, river and stormwater flooding vary by location. The Environment Agency's Flood Map *(www.environment-agency.gov.uk/subjects/flood)* shows floodplains in England and Wales that would naturally be affected by flooding if a river rises above its banks, or high tides and stormy seas cause flooding in coastal areas.

Property in an undefended floodplain is at highest risk of flooding. Increased economic wealth will also increase the value of losses. In 2004 the Foresight Future Flooding report[19] estimated that annual average flood damages could increase by 2 to 20 times by the end of this century.

# menu of strategies for managing flood risks

The diagram summarises the range of actions and techniques available to increase adaptive capacity. Detail is given in the text on the proceeding pages.

| Key | |
|---|---|
| | Conurbation/catchment scale |
| | Neighbourhood scale |
| | Building scale |



# 4.2.1 managing flood risks at the catchment scale

At the catchment scale the most significant risks will be from tidal and river floods. The aim should be to integrate green and built spaces with flood management strategies. Built environment professionals should take account of climate change and focus on opportunities to reduce flood risks through large scale infrastructure.

It is essential that flood risk management takes account of interactions over the whole catchment. Water storage should be incorporated into spatial plans and drainage 'pinch points', or barriers, should be avoided. Holding water in the upper parts of catchments can reduce downstream flooding. Structural flood defence schemes need to take into account the impact of climate change on the magnitude of risk, and incorporate designs which allow future adaptation.

Flood risk management strategies include:

- Strategic flood risk assessment and a sequential approach to development in the floodplain. The longer term implications of sea level rise may mean that decision-makers need to start thinking about moving particularly vulnerable settlements.
- Flood attenuation, or provision of temporary water storage capacity during flood events, to reduce peak flows. This includes creation of flood retarding basins and sacrificial areas (e.g. sports fields and car parks) that flood during extreme events.
- Upland land management though storage (e.g. reservoirs) and planting to reduce runoff.
- Managed realignment involves breaching existing hard coastal defences, such as sea walls, allowing land behind to be flooded. Vegetation disperses wave energy during storm events, reducing coastal erosion and providing habitats for coastal flora and fauna. This option can reduce the costs of coastal defence.
- Understanding flooding pathways in urban environments, to help manage the probability of flooding and its consequences.
- Hard, permanent flood defences and barriers.
- Diversion of flood flows away from vulnerable areas or constructing a second flood channel.
- SUDS to manage and slow down surface water run-off and release it to the natural water cycle. SUDS can deal with flood, water quality and resource risks while also bringing ecological and amenity benefits.

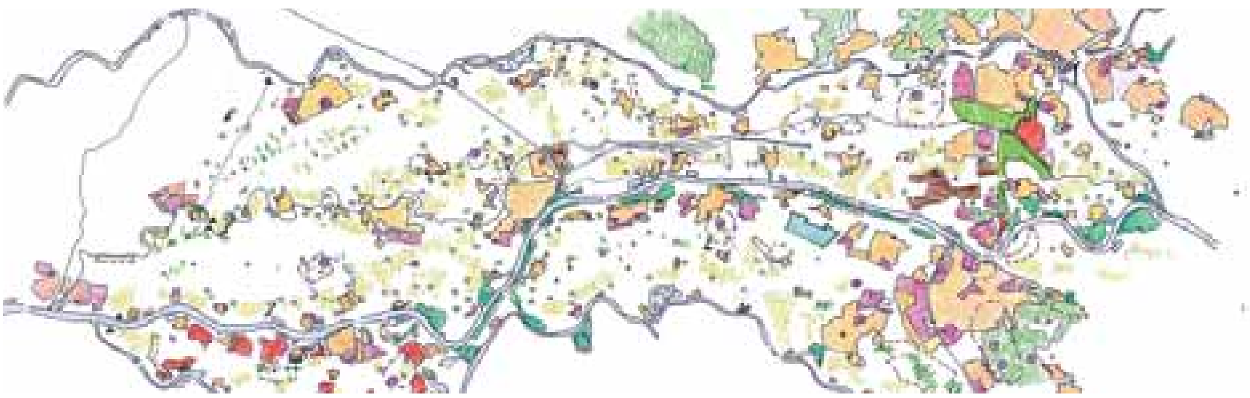
## case studies

**ESPACE Guiding Models for Water Storage, The Netherlands**

Space is at a premium and vulnerable to flooding in the low-lying and densely populated Netherlands. The European Spatial Planning: Adapting to Climate Events (ESPACE) project has developed 13 models for water storage for managing flood risks. These are practical strategies which emphasise a multi-functional approach to land use. For example, one model describes seasonal storage of flood water on agricultural land, with financial compensation to farmers who provide these 'blue services'.

In addition to practical examples of water storage strategies 'in the field', the models offer procedures to facilitate implementation and an emphasis on collaborative decision-making. The approach is broadly transferable to UK land use planning.

*More info: www.espace-project.org*



A component of the ESPACE Guiding Models tool. *Source: Robbert de Koning landscape architect BNT, Oosterbeek, The Netherlands*

### BETWIXT High Resolution Weather Scenarios

The BETWIXT[20] project has developed high resolution weather scenarios. Outputs include the RainClim software package, which creates rainfall time series for present day and future time periods, and the Climatic Research Unit weather generator. The Environment Agency has used these to develop the EA Rainfall and Weather Impacts Generator (EARWIG) tool.

*More info: www.cru.uea.ac.uk/cru/projects/betwixt*

### Coastal Realignment at Abbotts Hall Farmzz

The Blackwater estuary, one of the largest in East Anglia, covers almost 4,400 ha and is of national and international importance for nature conservation. One of the main threats to the estuary is 'coastal squeeze', where natural salt marsh is pinned against man-made flood defences by rising sea levels. Over the last 25 years up to 40% of the salt marsh has been lost.

The coastal realignment project at Abbotts Hall Farm was designed to allow for the regeneration of salt marsh. The scheme works by breaching hard defences and allowing salt water back onto land originally reclaimed by the construction of a sea wall over 300 years ago. Two counter walls have been constructed at either end of the site to protect neighbouring land. This has allowed the creation of 200 acres of mudflat, pioneer salt marsh and coastal grassland.

*More info: www.essexwt.org.uk/sites/Abbotts%20 Hall%20Farm.htm*

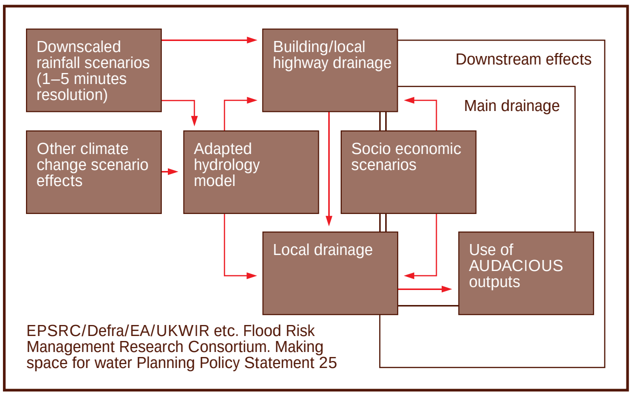
# 4.2.2 managing flood risks at the neighbourhood scale

At the neighbourhood scale, efforts should focus on understanding and managing flood pathways and protecting areas at risk. Well designed adaptation can have additional benefits for water quality and resource management, and enhance the public spaces.

Similar solutions from catchment flood risk management strategies can be applied at the neighbourhood level. These include:

- Strategic flood risk assessment and a sequential approach to development in the floodplain.
- Impermeable surfaces can be replaced by SUDS, such as permeable pavement, gravel or grass so that water can soak away. Within parks and greenspaces storage areas, such as infiltration ponds, can be constructed.
- Smaller scale hard barriers or managed realignment schemes.
- A second layer of setback flood defence constructed behind the original barrier. This is often used with managed realignment.
- Use of green open space and green roofs to reduce runoff and ameliorate pressure on drainage systems during heavy rainfall.
- Widening drains to increase drainage capacity.
- Managing flood pathways and removing 'pinchpoints' so that heavy rainfall can drain away.

Coastal realignment at Abbotts Hall Farm
*Source: Essex Wildlife Trust*




AUDACIOUS project scope
*Source: AUDACIOUS project*

# case studies

### Adaptable urban drainage, AUDACIOUS research project

The AUDACIOUS project took account of potential future changes in climate and urban form to evaluate solutions for urban drainage. It focussed on problems of flooding associated with surface water run-off and sewer surcharging linked to intense rainfall events. The project found that institutional barriers present a major challenge to managing flood risks, and underlines the importance of building capacity within stakeholder groups and clear distribution of roles and responsibilities. AUDACIOUS proposes using a surface water management plan (SWMP) to help understand flood risks and plan responses *(See image page 27)*.

Other outputs include:

- A new urban hydrology runoff model which is flexible enough to accommodate new information about climate change as this becomes available.
- New building drainage (storm and sanitary) simulation models.
- A new whole-life-cost risk based methodology for assessing flood risk and response effectiveness
- Guidance for building stakeholder capacity.

*More info: www.k4cc.org/bkcc/audacious*

### Canal Basin Regeneration, Gravesend

Gravesend is located within the Thames estuary and a significant portion of the canal basin regeneration site is part of the historic floodplain of low lying marsh. A Strategic Flood Risk Assessment (SFRA) has been undertaken to analyse the main risks. The site developer and architect have also used a site flood risk assessment to plan for extreme events.

Other flood management strategies include: setting back river edge flood defences to make space for water; incorporating flood flow paths and storage within the site; locating vulnerable uses in low risk areas; designing resilient buildings and emergency access routes; and incorporating SUDS. These will allow the local planning authority to apply a risk based approach to site allocation in the LDF and to development control decisions.

*More info: www.gravesham.gov.uk*

### Upton One Urban Extension, Northamptonshire

One of Upton's key features is its SUDS which manages rainwater run-off and promotes local biodiversity. Consisting primarily of linked swales, SUDS at Upton provide the underlying basis of the landscape structure, and is connected with the streets and built form. A company has been established to manage the SUDS and maintain communal courtyards. Rainwater harvesting has also been incorporated.

The plan was created through a collaborative design exercise putting the community at the heart of decision-making. Design Codes were used by partners as the basis for drawing up development briefs, and for assessing developer proposals prior to submission for planning permission. This strong community-oriented process emphasises environmental responsiveness and aims to minimise future running costs.

*More info: www.northampton.gov.uk*

Canal Basin Regeneration, Gravesend
*Source: Gravesham Borough Council*

Upton One Urban Extension, Northamptonshire
*Source: D. Waterhouse, TCPA*

# 4.2.3 managing flood risks at the building scale

The aim at this scale should be to minimise exposure to flooding whilst incorporating structural solutions to reduce vulnerability. New developments need to be carefully assessed to ensure that they are built to cope with flood risks as they change over time and that risks in adjacent areas are not exacerbated.

Existing buildings can take advantage of new materials and products to manage flood risks. Though it must be stressed that these strategies do not always make new development in the floodplain acceptable in flood risk terms – they are aimed at protecting existing development. The strategy should be to relocate vulnerable land uses out of the floodplain, including emergency services.

The proportion of sealed ground should be minimised, since this exacerbates flooding. Where possible, ground should be left or made permeable.

Flood risk management strategies at this scale include:

- Green roofs to reduce runoff and ease pressure on drainage systems.
- Managing flood pathways and removing 'pinchpoints' so that heavy rainfall can drain away.
- One way valves permanently fitted in drains and sewage pipes to prevent backflow and, as a last resort, widening drains to increase capacity.
- Flood resilient measures, including raising floor levels, electrical fittings and equipment; rain-proofing and overhangs to prevent infiltration of heavy rain around doors and windows; temporary free-standing barriers which hold back floodwater from properties.
- Flood resilient materials can withstand direct contact with floodwaters for some time without significant damage. These include concrete, vinyl and ceramic tiles, pressure-treated timber, glass block, metal doors and cabinets.
- Removable household products like flood boards, air brick covers and flood skirts which are fitted temporarily to properties to form a barrier to water. Pipes, drains and toilet bowls can be temporarily blocked using an expandable/ inflatable bung to prevent backflow. In cases of severe flooding, the stress caused by water volume can damage the structure and foundations of buildings, making it more harmful to keep water out than to let it in.

# case studies

### National Trust Properties, Boscastle

Following devastating floods at Boscastle in 2004, impermeable wall finishes on vulnerable buildings have been replaced with limewash. This allows walls to dry out after inundation. Internally, suspended floors have been converted to solid floors to reduce the impact of any future flooding, and electrical points have been raised off the ground. Floors in the Youth Hostel have been raised above the level of a 1 in 100-year flood.

The Engineering Historic Futures project provides better understanding of the wetting properties and drying processes in historic buildings.

*More info: www.nationaltrust.org.uk and www.ucl.ac.uk/sustainableheritage/historic_futures.htm*

### Genesis Centre, Taunton

Genesis, at Somerset College of Arts and Technology in Taunton, is a £2.5 million educational resource showcasing cutting edge techniques and materials for sustainable construction. The SUDS at Genesis uses landscaping to replicate natural drainage with a series of features to slow down surface water run-off and filter pollutants. Water is then slowly returned to a natural watercourse. The Centre also incorporates permeable paving in car parking bays, providing drainage through vertical channels to allow controlled release to sewers or water courses.

The performance of the materials and techniques used is monitored so that they can be measured against industry standards and against each other to assess fitness for purpose. The design is flexible and can be adapted with new technologies and materials.

*More info: www.genesisproject.com*

Genesis Centre, Taunton
*Source: The Genesis Project*

# 4.3 managing water resources and quality

**Changing patterns of rainfall will have a significant impact on water resources and water quality. In the summer, warmer temperatures will mean that demand for water grows just as supply – especially in water in rivers and underground aquifers – declines due to lower rainfall. Urban areas have little capacity to store drinking water and are more likely to experience shortages during droughts.**

Low river flows during dry summers can lead to restrictions on water abstractions, with consequences for industrial and mechanical cooling processes when the need for cooling is highest. Low river flows are less able to dilute pollutants, with knock-on impacts for water quality including eutrophication (where excess nutrients stimulate excessive plant growth) and algal blooms. Urban flooding and flooding of landfill sites can lead to pollutants entering watercourses or, in extreme cases, buildings. 'First flush' episodes, where sudden heavy rain falls after a long dry period, can also wash high concentrations of pollutants into streams and rivers.

Whereas high temperatures and heat waves are relatively new challenges, managing water resources and water quality is an ongoing priority with established responsibilities and procedures. Climate change is putting additional pressure on current water resource management systems, and traditional responses may not be adequate in the future.

Treating and distributing water for human use requires substantial energy resources (water industry GHG emissions were just over 4m tonnes of $CO_2$ equivalent in 2005/06[21]). Reducing the amount of water used can therefore make a significant contribution to reducing emissions.

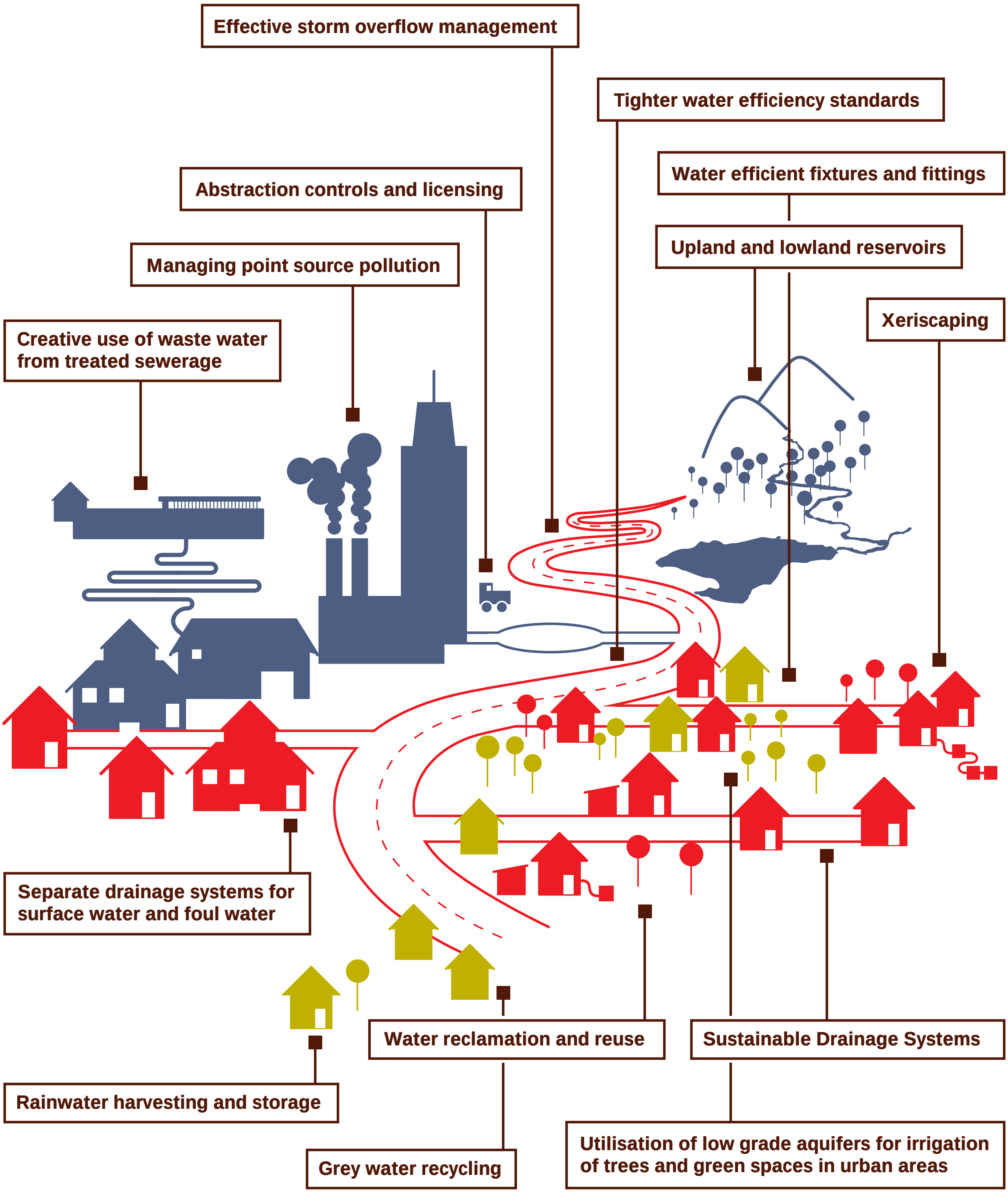
**Where is the imperative for adaptation greatest?**
Water resource and quality risks vary considerably by geographic location. Summer and winter precipitation is currently more plentiful in the north and west, and it tends to be higher in upland areas. The largest changes in precipitation in both winter and summer due to climate change will be experienced in eastern and southern parts of the UK – the changes in northwest Scotland are the smallest. The imperative for adaptation for water supply and quality risks is therefore greatest in the south and east, where water resources are in many cases already fully committed.

The Environment Agency produces maps showing current indicative availability of summer and winter surface water and groundwater for England and Wales as part of the Water Resources for the Future strategy.[22] This refers to climate change as a factor affecting future demand and supply, though it presents only current availability patterns. The Environment Agency has recently consulted on a methodology for designating 'water-stressed' areas. This can be used by planners to justify higher water efficiency standards in new development.

# menu of strategies for managing water resources and quality risks

**The diagram summarises the range of actions and techniques available to increase adaptive capacity. Detail is given in the text on the proceeding pages.**

| Key | |
|---|---|
| | Conurbation/catchment scale |
| | Neighbourhood scale |
| | Building scale |



# 4.3.1 managing water resources and quality at the catchment scale

At the catchment scale, managing water resources and quality already focuses on safeguarding clean rivers and lakes that sustain diverse and healthy ecosystems, provide recreation opportunities, and support the needs of communities. When planning for change, developers, architects, planners and urban designers will need a shared vision to ensure that any new development or regeneration is designed to take account of the effect of a changing climate. Consideration of the current and likely future capacity of water resources and wastewater treatments should be incorporated in masterplans, concept statement or Area Action Plans.

Water quality and resource management efforts should focus on opportunities offered through changes in large scale infrastructure. Development and change should integrate water, open space and the built form through greenspace and bluespace strategies. It is important to think further about catchment water management in a holistic way. Effective water resource management can also assist with flood risk management and provide leisure opportunities.

Strategies for water resource and quality management include:

- Upland and lowland reservoirs, both natural and manmade, help to ensure sufficient water supplies during summer while reducing the potential for flooding downstream during heavy rainfall. They also have important aesthetic, recreation, ecological and flood storage roles.
- Treated waste water may be disinfected chemically or physically (e.g. by lagooning and micro-filtration), and the final effluent can be used for irrigation.
- Promoting tighter water efficiency standards (through, for example, policies in regional and local development plans) in areas where there is water stress. Especially since stress is likely to worsen in the future.
- Encouraging use of SUDS (described earlier) for groundwater recharge.
- Abstraction controls and licensing to manage the needs of water users while ensuring adequate protection of the environment.
- Greater use of separate drainage systems for surface and foul water, to send surface water runoff directly back to the watercourse and significantly reduce the treatment burden.
- More use of reclaimed and recycled water, produced after advanced treatment and filtering of wastewater and stormwater. This results in high quality water suitable for irrigation and non-drinking water uses such as toilet flushing.
- In order to sustain the evaporative cooling function of vegetation rainwater harvesting, underground storage and accessing new supplies of lower grade ground water may provide additional water in times of drought. In other situations it may be more suitable to use low water use planting or xeriscaping to create public and private landscapes that do not require irrigation.

Many of these strategies are already being used. The challenge for built environment professionals will be to adapt strategies to take account of climate change. Hotter, drier summers may mean new reservoirs are required. Current sewage treatment standards may need tightening, though this will have energy resource implications. Abstraction controls may also need to become stricter. Innovative approaches at the catchment scale are used in parts of the world that already experience severe water resource pressure, such as Singapore and New Mexico.

# case studies

## Urban water management, Singapore

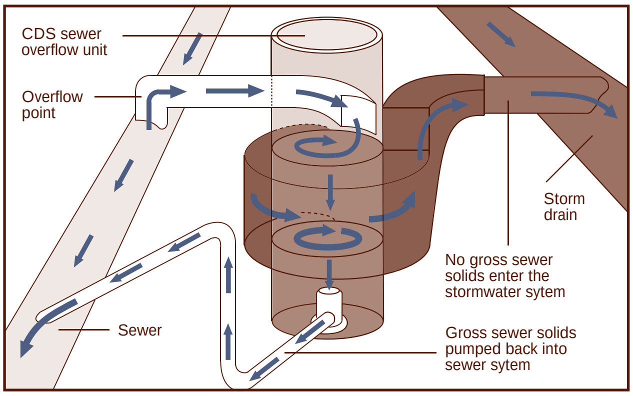
Long-term water security is an important consideration for Singapore – a water-scarce country – not because of lack of rainfall, but because of limited land area to store rainfall. The country has implemented separate drainage and sewerage systems, which facilitates re-use of wastewater on an extensive scale. Recycled wastewater (called 'NEWater') is currently used for industrial and commercial purposes only, though it is safe to drink. Because its purity is higher than tap water, it is ideal for industrial manufacturing and high tech processes which require ultra pure water. Singapore is one of the very few countries that looks at its supply sources in its totality, concurrently managing supply and demand, wastewater and stormwater management, with an emphasis on institutional effectiveness.

*More info: www.thirdworldcentre.org/iijwrd.html*

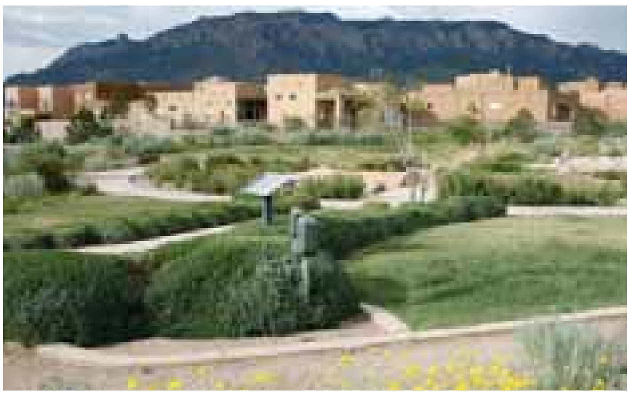
## Xeriscaping in Albuquerque, New Mexico

Faced with increasing demands on existing water supplies, and the prospect of future population growth, the City of Albuquerque encourages conservation of water through an extensive programming of creative landscaping. The City offers substantial rebates on water charges for households with xeriscaped gardens, incorporating plants selected for their water efficiency. The Water Utility Authority provides a comprehensive support to homeowners, including xeric design templates, low-water plant lists and other guidance. Albuquerque was awarded a World Leadership Award in 2006 for sustainable water management planning.

*More info: www.cabq.gov/sustainability/sustainability/green-goals/water/water*




CDS sewer overflow unit
*Source: Water Industry Operators Association, Australia*



Xeriscaping in Albuquerque, New Mexico
*Source: Sites Southwest*

# 4.3.2 managing water resources and quality at the neighbourhood scale

Efforts to manage pressures on water resources and quality at this scale should aim to enhance public spaces and contribute to other objectives. For example, rainwater harvesting and storage schemes reduce risk of urban flooding while simultaneously providing additional water supplies.

Efforts to manage water resources and water quality should work with catchment scale measures to incorporate climate change adaptation into regeneration areas, new and existing communities. Designers and planners will also need to ensure that water resource management efforts do not unduly increase energy requirements and conflict with GHG emission reduction targets. Design Codes provide a useful tool for managing conflicts and ensuring a development's compliance with the overall concept of resilience.

The following strategies can be implemented:

- Rainwater harvesting and storage from roofs or other surfaces for future use (normally toilet flushing and irrigation). This strategy can also increase soil moisture levels for vegetation, sustaining evaporative cooling and reduce risk of urban flooding.
- SUDS to collect and store water.
- Grey water recycling to use waste water from plumbing systems for toilet flushing and irrigation.
- Xeriscaping, or low water use planting, can greatly reduce water demand.
- Effective storm overflow management prevents surface water contamination.
- Managing point source pollution reduces water quality risks.

# case studies

### Greenfields Sustainable Construction, Maidenhead

The Greenfields scheme, completed in 2001, was designed to connect environmentally friendly features with technology, providing a more holistic approach to sustainable construction.

The 19 flats and 8 houses in this scheme incorporate a grey water recycling system which reuses waste water from baths, showers and hand basins for flushing toilets. Low-flush toilets and water efficient taps have been installed. Surface water from the roofs is collected, treated with UV light to kill bacteria and then stored underground for communal garden watering.

The £2m Greenfields project cost approximately 10% more than a conventionally developed scheme. It is anticipated that savings to tenants will be in the region of 30% for water consumption. Monitoring is taking place to measure this.

*More info: www.rbwm.gov.uk/web/eh_sustainable_homes_greenfields.htm*

### Wessex Water Operations Centre, Bath

This award-winning site incorporates water conservation measures, on-site surface drainage, and an integrated water management network to avoid discharging surface water via a new sewer into the local rivers. Permeable paving in the car parking area allows rainwater to percolate into soakaways which supply irrigation to the grounds. A swale runs down the edge of the site and drains to the main storage tank. Water from the tank is pumped back to soakaways to feed an ornamental water feature. Roof run-off and treated grey water provide 95% of flush toilet water.

*More info: www.wessexwater.co.uk/operationscentre/*

SUDS at Upton One Urban Extension, Northamptonshire
*Source: D. Waterhouse, TCPA*

Wessex Water Operations Centre, Bath
*Source: Wessex Water*

## 4.3.3 managing water resources and quality at the building scale

At the building scale, designers, developers and architects can exploit synergies between water resource management, flood risks and energy conservation. For example, green roofs can regulate interior temperature leading to energy conservation; they can also reduce runoff and lower flood risk while storing water to satisfy a portion of the building's demand.

A number of solutions offer effective means of managing water supplies and reducing demand:

- Water efficient fixtures and fittings can significantly reduce demand for water, and these will become increasingly important for high density developments.
- Rainwater harvesting and storage (described earlier). Grey water can then be recycled for irrigation.
- Building scale SUDS will reduce runoff and satisfy a portion of the building's demand for water. Green roofs have an important part to play.

## case studies

### Red Kite House, Wallingford

This building, constructed at a cost of approximately £4.5 million, uses a harvesting system to collect rainwater from the roof for re-use within the building. The system satisfies about 40% of the building's annual water demand. Overspill from the rainwater harvesting storage tank is directed into a reed bed and back to the natural watercourse.

The drainage system is designed to reduce the impact of run-off on river systems. The 94-space car park uses pervious blocks, which allow rainwater to soak through into the ground. A geotextile membrane below the blocks traps oil and other pollutants.

*More info: www.environment-agency.gov.uk/regions/thames/323147/1205605/*

### 'The Hub', Newham, London

This new community resource centre in Newham incorporates water and energy conservation features. These include low consumption fittings in bathroom areas, and toilets are flushed from rainwater collected from the roof. Harvested rainwater is also used for plant irrigation. A rainwater storage tank, which serves as an irrigation system for the planted walls, has been constructed below external play areas and is expected to contribute to a saving in mains water of around 50% per year.

'The Hub' was commissioned at a cost of almost £3m, and is an example of sustainable design achieved through a clear community vision. A key mechanism of the programme includes putting communities themselves at the heart of decision-making.

*More info: www.betterpublicbuildings.gov.uk*

Red Kite House, Wallingford
*Source: Environment Agency, 2007*


The Hub, Newham, London
*Source: Dennis Gilbert/VIEW*

# 4.4 managing ground conditions

**Ground conditions and land stability are affected by temperature, precipitation, winds, and wave action, in addition to physical factors such as mining activity, road building or vegetation. Climate change will have significant impacts on ground conditions in some areas.**

Methods for managing land stability should take into account the potential for subsidence, heave, erosion, and landslip. During longer, hotter summers shrinkable clay soils are likely to dry out, making buildings and service pipes vulnerable to cracking. Wetter winters will contribute to risks of 'heave' where ground swells. Shrinking and swelling of the ground is one of the most damaging geohazards in Britain today. According to the British Geological Survey this has cost the economy an estimated £3 billion over the past decade. To counter this effect, existing buildings can be underpinned and new buildings can incorporate improved foundation design.

Because erosion is closely related to flood risks on coasts, geotechnical experts should work closely with flood risk managers to respond effectively to both challenges. New approaches to design, funding and management of land stability measures may be required in order to respond to the new pressures that climate change will bring.

**Where is the imperative for adaptation greatest?**

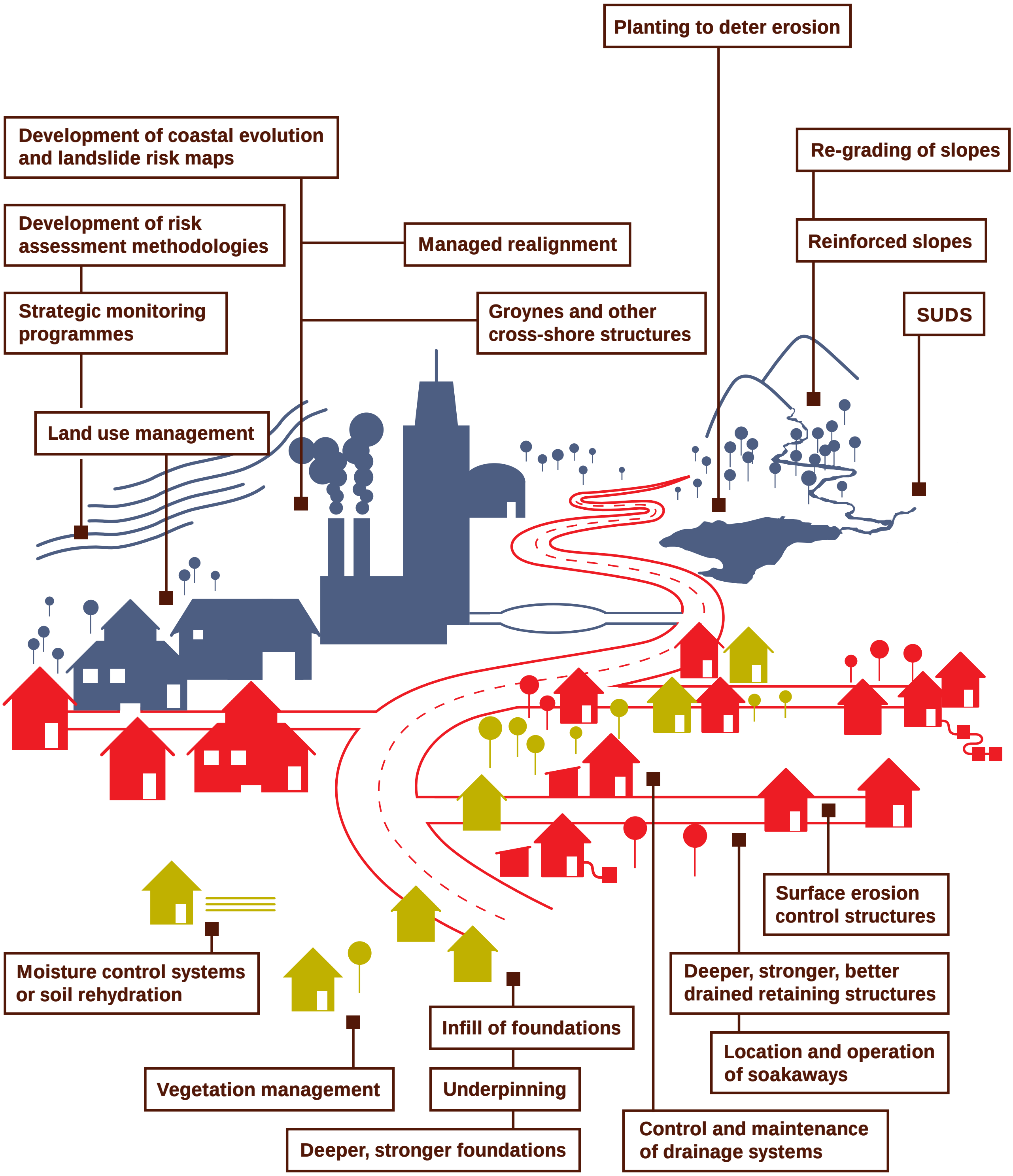
The risk of subsidence and heave is strongly dependent on local soil type, and varies considerably with location. Many soils contain clay minerals that swell when wet and shrink as they dry. The British Geological Survey produces a national GeoSure dataset that identifies those areas that are currently most at risk. The most susceptible land is found mainly in the southeast of the UK. In the future it is sensible to assume that these areas, which will experience the most significant decreases in summer precipitation, will also be at highest risk of subsidence and heave.

Erosion and landslip are influenced by slope, soil type, flow of water, and vegetative cover. Coastal areas are vulnerable, as are embankments, cuttings, and steep and/or unvegetated cover. As sea levels rise the risk of coastal erosion will increase.

# menu of strategies for managing ground conditions

The diagram summarises the range of actions and techniques available to increase adaptive capacity. Detail is given in the text on the proceeding pages.

| Key |
|---|
| Conurbation/catchment scale |
| Neighbourhood scale |
| Building scale |



# 4.4.1 managing ground conditions at the conurbation scale

At this scale, current efforts to manage ground conditions focus on coastal, landslide and cliff management and monitoring, and ground stability engineering. From now on, conurbation scale actions will need to take account of climate change impacts.

Adaptation to ground condition risks should concentrate on largescale monitoring activities, risk assessment and mapping, and opportunities for using infrastructure to improve land stability.

Current and likely future climatic risks to ground conditions should be assessed and incorporated into development plans. This is vital to ensure that development does not constrain our ability to deal with land stability risks in the future.

If well designed and integrated, strategies for management of ground conditions, such as vegetated slopes and managed realignment, can provide amenity by enhancing the quality of public places.

PPG 14 (Development on Unstable Land – Annex 2: Subsidence and Planning) sets out advice for planners. This and the following strategies should be used and strengthened to take account of climate change:

- Development of risk assessment methodologies to improve understanding of coastal erosion risk and evolution in the long term.
- Development of coastal risk and evolution maps and, where appropriate, more detailed maps on landslide risk.
- Strategic monitoring programmes to assess changes in ground conditions or coastal change.
- Land use management, including vegetated slopes and agricultural systems management.
- Managed realignment and avoidance of development in areas at high risk.

## case studies

**Landslide management on the Isle of Wight**

The Isle of Wight Council has developed a Landslide Management Strategy in response to aggressive coastal erosion. It aims to reduce the likelihood of future ground movement and to limit the impact of movement through the adoption of appropriate planning and building controls. A model of current ground behaviour has been developed based on geomorphological mapping. The strategy involves monitoring ground movement, site investigations, damage surveys, determination of past movement rates and a review of historical events.

The Isle of Wight's Centre for the Coastal Environment led a 3-year multi-partner EU project, called RESPONSE, to develop strategies that assist local authorities and other stakeholders with managing coastal risks, taking account of the impacts of climate change. Project outputs are designed to identify future risks. They include a training pack detailing the process of developing coastal evolution and risk maps, information on the costs of managing natural risks and best practice advice. A non-technical guide assists end-users in addressing climate change impacts in developed coastal areas in a sustainable way.

*More info: www.coastalwight.gov.uk/*

Coastal landslide, Niton Undercliff, Isle of Wight
*Source: Isle of Wight Council. Courtesy of Wight Light Gallery*

Ventnor, Isle of Wight
*Source: Isle of Wight Council. Courtesy of Wight Light Gallery*

**Local government risk assessment, New Zealand**

A risk assessment and management plan is being developed by Local Government New Zealand (LGNZ) to protect homes and businesses from landslides and floods. The plan follows a call from Insurance Council chief executives for New Zealanders to take climate change into account in order to manage land more effectively. Management measures might include a change of land use, increasingly stringent building or development requirements, or imposing conditions regarding tree planting. Relocation of at-risk houses would also be considered.

*More info: www.lgnz.co.nz/projects/ClimateChange*

**BIOlogical and eNgineering Impacts of Climate change on Slopes (BIONICS)**

Climate change is expected to have a serious impact on large parts of the UK's infrastructure. No strategy yet exists to facilitate the planning required to act upon it. The aim of the project, which forms part of the BKCC portfolio[1], is to improve understanding of climate change impacts on slope stability. While the project is still in progress, outcomes will be computer models to predict embankment performance under present and future climates and a fully integrated building and fabric moisture model.

*More info: www.ncl.ac.uk/bionics*

Road removed by a landslide. Villa Real district, Portugal
*Source: Nuno Cristelo*

# 4.4.2 managing ground conditions at the neighbourhood scale

At the neighbourhood scale, the focus should be on opportunities to incorporate adaptation within existing neighbourhoods and new developments. Synergies with flood risk and water resources management exist at this scale.

These include effective management of urban flash flooding through SUDS, and soakaways to reduce land stability risks. However, reductions in soil moisture may increase risks of subsidence and landslip.

Ground condition risks can be managed through:

- Structural changes or improvements in external surface protection, such as vegetative cover.
- Vegetation management, including careful choice and placement of trees to avoid building subsidence in shrink-swell soils and planting to deter erosion on dunes and sandy soils.
- Re-grading or reinforcing of slopes to reduce risk of erosion and landslips.
- Surface erosion control structures, including retaining walls and fences.
- Deeper, stronger, better drained retaining structures.
- Use and operation of soakaways and SUDS.
- Maintenance of drainage systems, including channel management.
- Groynes and other cross-shore structures and toe protection structures.

## case studies

### Kings Cross Underground Station redevelopment, London

The redeveloped Kings Cross underground station is one of the busiest underground stations in London. The station has a design life of 120 years. Risk assessments have considered future aquifer levels and evaluated the behaviour of underground water movement to determine potential flood and heave risks throughout the project's life. All these issues were taken into account in the development's design, and additional robustness was built into the foundation design to take account of potential risks.

*More info: www.arup.com*

### Big Buddha Road, Hong Kong

Engineers will remove shotcrete – the skin of concrete applied to slopes all over Hong Kong – from steep cuttings along the popular tourist route to the Big Buddha in an experiment they hope will reduce landslide risk and return greenery to the hillsides. The 20 slopes on South Lantau Road are ageing and in need of repair. Until recently shotcrete was regarded as a necessary evil, but there has been criticism from geologists, engineers and environmentalists who argue shotcrete may actually increase the risk of landslides. Shotcrete, unlike vegetation and trees, does not bond to a slope – it simply covers it, providing the illusion of stability rather than support. The shift away from spray-on concrete also aids the push to use Hong Kong's country parks as a lure for tourists. The Lantau project is important because it may become a model for future projects all over Hong Kong.

*More info: www.cedd.gov.hk/eng/projects/landslip/index.htm*

## 4.4.3 managing ground conditions at the building scale

At the building scale, efforts to reduce vulnerability to subsidence or landslip are focused on appropriate construction. Some synergies and conflicts exist at this scale and architects and designers will need to take a balanced approach to managing various risks.

For example, heavier foundations and infill – beneficial for managing ground conditions – may also help to reduce heat risks. Flexible, timber-framed construction, however, is effective in managing subsidence risk but may not cope as well with overheating and flood risks.

Strategies for managing ground conditions include:

- Vegetation management must include careful consideration of size, species and placement of trees to avoid subsidence of buildings on shrink-swell soils. Though vegetation helps to reduce runoff and landslip risk at larger scales, trees can cause damage to the built environment through disruption or displacement of structures as trees grow, through direct damage as branches fall, or because they abstract water from soils leading to soil shrinkage.
- Ensuring at the design stage that foundations are strong enough and extend downward below the zone that may be affected by seasonal variations in moisture content.
- Underpinning with concrete supports that extend under existing foundations into more stable soils.
- Infill of foundations.

King's Cross St. Pancras Underground Station, London
*Source: ARUP*

Shotcrete application
*Source: Shotcrete Services Ltd*

- Control and maintenance of drainage systems, including channel management.
- Regrading and reinforcement of slopes to reduce risk of erosion and landslips.
- Stronger retaining walls and fences with good drainage for surface erosion control.
- Soakaways and SUDS.
- Moisture control systems or soil rehydration to prevent further damage and correct existing problems. Availability of water will be a consideration for this strategy.

## case studies

### CLASP system of flexible construction, UK

CLASP (Consortium of Local Authorities Special Programme) principles have been used since 1957 to incorporate flexibility into building design to resist subsidence. CLASP construction relies on a high proportion of prefabricated elements and has the advantage of being appropriate for sites with poor ground conditions.

CLASP advocates using flexible timber-framed construction techniques rather than more rigid concrete or brick-frames, dividing larger structures into smaller units with expansion and compression joints between them, and introducing gaps or joints into foundations, structures or services to compensate for strains. The design allows production of components that can quickly be erected on site, whilst allowing flexibility of design and changes during the lifetime of the building. The CLASP system itself has evolved to meet changes in building standards and regulation.

CLASP has successfully been used in more than 3,500 buildings in the UK, and buildings have been constructed throughout the world. In 2004 the Consortium reviewed CLASP technology with the objective of making sustainability its key driver. The revised principles are now referred to as Scape.

CLASP's flexible, timber-framed design has proved effective in managing subsidence risk, but it may not cope as well with overheating and flood risks. Planners, developers and designers will need to carefully weigh up their vulnerability to subsidence and other climatic risks.

*More info: www.clasp.gov.uk*

### Joint Mitigation Tree Root Protocol, London

This pilot project, currently being tested in the London boroughs of Barnet, Islington and Southwark, will help to fast-track subsidence claims by laying out a more co-operative way for insurers and local authorities to work together. Trees are often blamed for subsidence damage, and it is common for insurers to ask for trees to be removed. This is not always necessary. The protocol, put together by The Subsidence Forum, should clarify when trees are implicated in a subsidence claim by specifying the type of evidence required, setting down response times for both insurers and local authorities, and introducing a new formula for calculating the value of trees.

*More info: www.questgates.co.uk/news/article120.html*

CLASP system of flexible construction, UK
*Source: Scape System Build Ltd*

Urban green space at Hampstead Garden Suburb
*Source: R. Shaw, TCPA*

# techniques and technologies

This section provides further details on some of the key technologies available to help manage climatic risks.

# 5

# sustainable drainage systems (SUDS)

Sustainable Drainage Systems (SUDS) offer an alternative to traditional approaches to managing runoff from buildings and hardstanding. SUDS mimic natural drainage patterns and can reduce surface water runoff, encourage recharge of groundwater, and provide amenity and wildlife enhancements. By employing pollutant trapping and degradation processes, SUDS can protect water quality.

SUDS approaches include:

- Preventive measures including good housekeeping and rainwater harvesting.
- Reduced UHI effect by filter strips and swales. These are vegetated landscape features with smooth surfaces and a gentle downhill gradient to drain water evenly off impermeable surfaces.
- Infiltration devices, such as soakaways, which allow water to drain directly into the ground.
- Green roofs (see below) and reuse of water.
- Permeable and porous pavements.
- Basins, reed beds and ponds designed to hold water when it rains.

It is important that consideration is given to the long term maintenance requirements of SUDS, including the need to remove silt, and that space requirements for maintenance are allowed for in the design.

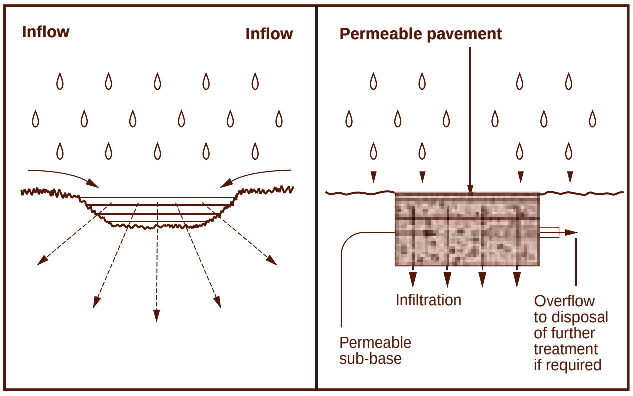
**Resources:**

CIRIA's SUDS website www.ciria.org.uk/suds, which includes the SUDS manual (C697, free to download)

Environment Agency SUDS advice www.environment-agency.gov.uk -> search on "SUDS"

UK SUDS Database www.suds-sites.net

Guidance on soakaway design (BRE365) is available from the Building Research Establishment www.bre.co.uk/




SUDS (right) mimic natural drainage systems (left)
*Source: Environment Agency*

# green roofs

Green roofs are vegetated roofs, or roofs with vegetated spaces. The main benefits include:

- Stormwater management, and hence potential savings to developers since the number of drainage outlets required on a building can be reduced.
- Reduced urban heat island effect by reducing building heat loss and increasing evapotranspiration.
- Creating natural green spaces in urban areas bringing benefits for biodiversity.
- Reduced energy consumption and fuel costs, since green roofs provide cooling in summer and thermal insulation in winter.
- Reduced air pollution.
- Extended roof life. The green roof protects the roof's waterproofing membrane, almost doubling its life expectancy.

**Resources:**

Living Roofs www.livingroofs.org

Green Roofs for healthy cities www.greenroofs.net

The Schachermayer factory green roof in Linz, Austria
*Source: Municipal Planning Board of Linz*

# structures and products to improve flood resilience

Permanent flood defences are normally the preferred means of protection. In many instances, however, permanent structures are not appropriate on cost, environmental or other grounds. This has led to growing use of temporary free-standing barriers which hold back floodwater locally.

A third solution involves removable measures, such as flood boards and air brick covers, which are fitted temporarily to individual properties to form a barrier. To use these to best effect, consideration needs to be given to the fabric of individual building (walls, services, floors, and so on) and how they respond to the pressure of the floodwater above and seepage below ground level.

Other measures, such as more water-resistant walls and sealing cracks, may also be necessary to reduce pathways through which water can seep into buildings. *See diagram below right.*

CIRIA has produced a series of advice sheets on improving the resilience of homes to flooding. These include advice on risk assessment, and practical steps to prevent, or reduce the impact of, flooding in the future, such as:

- Using one-way valves in drainage pipes to prevent back-up of water into buildings.
- Using removable flood barriers and other household measures.
- Using flood-resilient materials.
- Locating electrical services and boilers above likely maximum flood level,
- Raising damp-proof courses.

**Resources:**

CIRIA: www.ciria.org/flooding

Association of British Insurers (ABI): fact sheet on Flood Resilient Homes www.abi.org.uk > publications > flooding

Department of Communities and Local Government: ‘Preparing for Floods’ document www.communities.gov.uk > building regulations > approved documents and associated guidance

Environment Agency: ‘Damage limitation – how to make your home flood resistant’ document www.environment–agency.gov.uk/subjects > flood > floodline

# cool roofs, building and pavement materials

A ‘cool’ or ‘white roof’ can lower the temperature of a building’s roof dramatically and help to reduce the overall UHI effect. Cool roofs, on flat or sloping roofs, have a coating of light-coloured water sealant which reflects and radiates more heat than dark surfaces. By limiting the amount of absorbed solar energy, damage from ultraviolet radiation and daily temperature fluctuations – which cause repeated contraction and expansion – can be reduced.

Cool roofs do not offer all the advantages of green roofs in terms of stormwater runoff, air quality and nature conservation, but they do demand less investment. Furthermore, cool roofs are most effective on buildings with high roof-to volume ratios, such as one or two storey buildings.

Many urban roofs, streets and pavements are typified by dark surfaces. ‘Cool’ or ‘porous pavements’ offer an effective way of reducing urban temperatures and also encourage water storage. They:

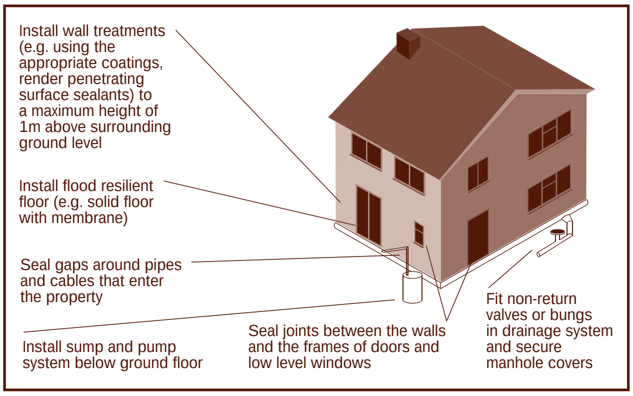
- Allow evaporative cooling.
- Water vegetation naturally, reducing the need for irrigation.
- Recharge ground water and preserves water resources.
- Reduce stormwater runoff.
- Improve water quality by reducing pollutants in the runoff.

**Resources:**

US Environmental Protection Agency www.epa.gov/heatisland/strategies/coolroofs.html

Cool communities www.coolcommunities.org

Climate technology www.climatetechnology.gov > library > cool materials




Flood protection measures
*Source: Environment Agency*

# rainwater harvesting and storage systems

Rainwater harvesting captures and diverts rainwater. The captured water can be used for irrigation purposes, car washing or toilet flushing. It is beneficial for two reasons:

- It reduces water demand, easing pressure on the mains water supply.
- It helps to reduce the risk of flooding during storms by storing rainwater and buffering run -off before it reaches the drainage system.

Typically, rainwater is collected from rooftops and is diverted into barrels or storage tanks. The amount of rainwater collected from a rooftop can be significant. A $100m^2$ roof can catch 500 litres of water from rainfall of just 5mm.

**Resources:**

The Rainwater Harvesting Community www.harvesth2o.com

Harvesting rainwater for landscape use ag.arizona.edu/pubs/water/az1052

Rainwater harvesting techniques www.toolbase.org > technology inventory

Linked rain barrels storing rain water
*Source: www.harvesth2o.com*

# greywater recycling

Greywater recycling has long been practiced in areas where water is in short supply and includes water from baths, sinks and laundry. It can be re-used for toilet flushing provided filtration and disinfection mechanisms are in place. The benefits include reducing household water demand and easing pressure on the mains water supply, reducing upstream energy and environmental costs. These systems require maintenance to ensure that they function correctly.

When properly managed, greywater can also be a valuable resource for horticultural and agricultural growers as well as home gardeners. It can also be valuable to landscape architects, builders, developers and contractors because of the design and landscaping opportunities afforded by on-site greywater treatment and management.

**Resources:**

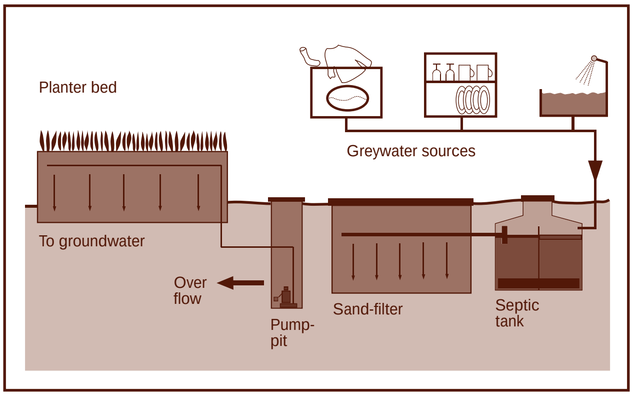
Greywater: what it is, how to treat it, how to use it www.greywater.com

Chartered Institution of Water and Environmental Management (CIWEM) www.ciwem.org

GROWing the Next Generation of Water Recycling Plants www.epsrc.ac.uk/PressReleases

WaND programme (Water Cycle Management for New Developments) www.wand.uk.net

Water Works UK www.wwuk.co.uk




Advanced greywater treatment
*Source: Carl Lindstrom*

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### Useful organisations

- BRE provides consultancy, testing and research services covering all aspects of the built environment. See www.bre.co.uk.
- CABE promotes design and architecture to raise the standard of the environment. See www.cabe.org.uk
- CIBSE Chartered Institution of Building Services Engineers. See www.cibse.org
- CIRIA produces best practice guides, advice notes and training packs for the construction industry on a variety of topics including ground engineering, surface water drainage and flooding, water supply and sewerage, and sustainability. See www.ciria.org
- CLIFFS Climate Impact Forecasting for Slopes network based at Loughborough University. See http://cliffs.lboro.ac.uk
- Environment Agency provides guidance on managing flood risk, improving water quality, protecting water resources and improving biodiversity. See www.environment-agency.gov.uk
- HR Wallingford is involved in research on flood risk management, drainage and water resources/irrigation. See www.hrwallingford.co.uk
- Project for Public Spaces (PPS) is a non-profit organisation dedicated to creating and sustaining public places that build communities. See www.pps.org
- Tyndall Centre works to develop sustainable responses to climate change through trans-disciplinary research and dialogue. See www.tyndall.ac.uk
- UK Climate Impacts Programme (UKCIP) helps organisations assess how they might be affected by climate change, so they can prepare for its impact. UKCIP is developing an over-arching Adaptation Wizard which is designed to help users move from understanding climate change to integration of climate risk management in decision-making. UKCIP also provides guidance on creating a Local Climate Impacts Profile (LCLIP), scenarios of climate change, risk management and costings methodologies, and other tools and support. See www.ukcip.org.uk

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