3.17 Urban precipitation and drainage

In this section you will learn about:
- urban precipitation, surfaces and catchment (drainage basin) characteristics
- impacts on drainage basin storage areas
- the urban water cycle: water movement through urban catchments as measured by hydrographs

Urban precipitation, surfaces and catchment characteristics

We have seen in 3.14 that urban areas have 5–15 per cent more precipitation than rural areas mainly because:

- warmer air in cities can hold more moisture
- dust and pollution make more condensation nuclei.

However, less vegetation and therefore less evapotranspiration reduces moisture in the air (humidity). Less vegetation also means less interception and more precipitation landing on hard, urban surfaces. The slate, tile, concrete and tarmac used in urban areas are impermeable and so the urban catchment is dominated by surface runoff (overland flow), particularly in city centres (Figure **1**). Both shallow and deep infiltration is significantly reduced and drains are therefore needed to remove surface water quickly.

Impacts on drainage basin storage areas

Drainage basins act as systems of inputs, transfers, outputs and stores (see *AQA Geography A Level & AS Physical Geography*, 1.1). The relationship between these variables is dynamic – they will change with circumstances. Urbanisation is especially significant in altering storage.
For example:

- Urban rivers are primarily the exit for water transferred through the drainage basin, but they are also important stores. Management of river channels by dredging, embanking and **channelisation** will increase their storage capacity.
- Reservoirs, lakes, ponds and swimming pools are permanent stores, but vulnerable to evaporation.
- Depression storage, such as surface puddles, following rain is temporary.
- Interception storage is reduced owing to the replacement of vegetation by impermeable structures such as buildings, roads and pavements engineered to drain the water rapidly into the nearest river.
- Soil moisture storage will vary according to ground conditions. For example, clay soils retain more water than sandy ones. However, there is usually less soil storage capacity as urban development reduces exposed surfaces and vegetated areas.

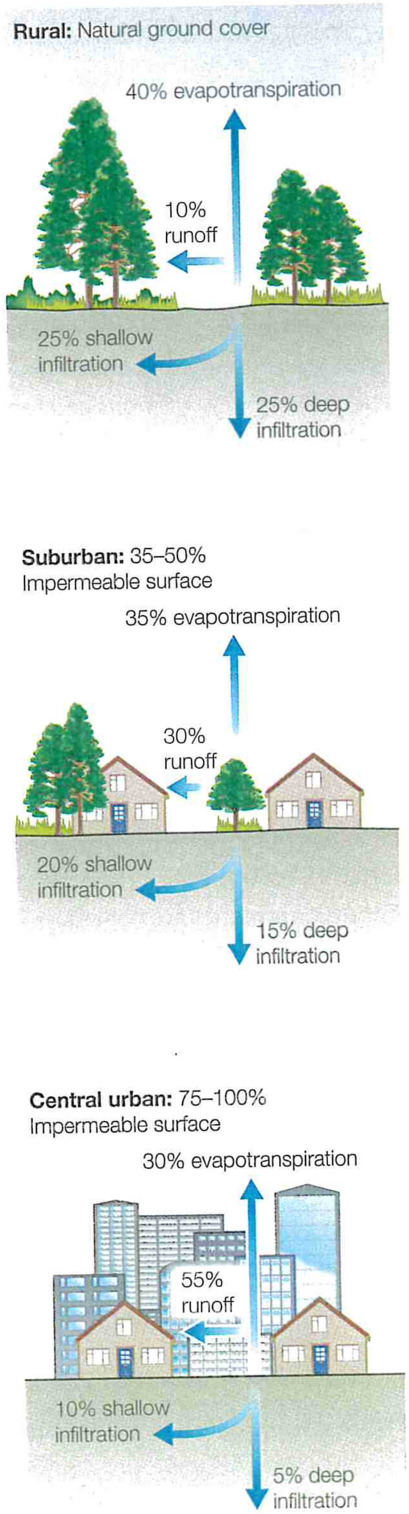

Figure 1 *Catchment characteristics change depending on the nature of the surface; rural, suburban and central urban land uses vary markedly in their percentage losses*

The urban water cycle: flood hydrographs

Look again at *AQA Geography A Level & AS Physical Geography*, 1.6. A flood hydrograph shows how river discharge responds to storm events. Measuring, recording and understanding the relationship between discharge and precipitation is essential in urban areas because of the increased flood risk caused by:

- the higher proportion of urban precipitation making its way into urban river channels
- the speed that this happens (shown by reduced lag times).

Look at Figure **2**. Urban hydrographs are 'flashy' – they show a rapid rise in discharge over a short period of time which produces a 'peaky' graph. This is because water is mainly entering the river via surface runoff.

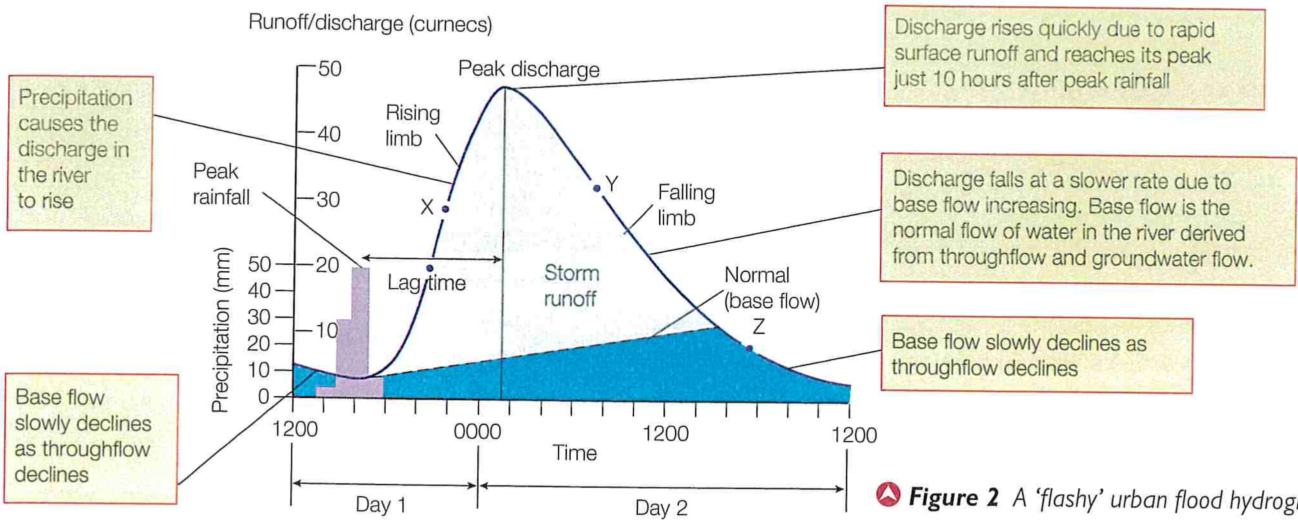

Figure 2 *A 'flashy' urban flood hydrograph*

Urban areas are not solely responsible for flooding – a town or city is likely to represent only a small area of the drainage basin as a whole. But, the need to build on floodplains to meet the increased demand for housing and the high proportion of impermeable surfaces certainly increases the threat. On occasions, therefore, heavy rainfall in urban areas can cause flash flooding as water flows rapidly along roads and pavements. Drains may be unable to cope with the sheer volume of water, and culverts may become blocked with debris. Furthermore, urban rivers themselves can get blocked by debris, particularly where bridges narrow the channel and so constrict the flow (Figure **3**).

Figure 3 *Torrential rain and hail caused the River Wey to burst in banks in Guildford, December 2013*

ACTIVITIES

1. Study Figure **2**.
   a. Copy and complete the following. State reasons for each one:
      - The lag time is the ...
      - At point X, surface runoff and discharge are ...
      - At point Y, discharge is ...
      - At point Z, there is no longer an input from surface runoff and throughflow and base flow are both ...
   b. If the channel capacity at the measuring point is 30 cumecs, what is inevitable, and when?
2. Study Figure **1**. Comment on the relationships between vegetation cover and the impermeable surfaces associated with urban areas.

STRETCH YOURSELF

Sketch a flood hydrograph in a rural area. The discharge will not rise so high. The lag time will be extended over a longer period of time because more water is entering the river via throughflow and groundwater flow, and less via surface runoff.

3.18 Drainage management

In this section you will learn about:

- management of drainage within urban catchment areas
- Sustainable Drainage Systems (SuDS)

Management of drainage within urban catchment areas

The rapid removal of water from urban surfaces is essential if day-to-day city life is to continue normally. But, efficient drainage into nearby rivers is only viable if they can cope with the huge volumes of water entering them. Otherwise, flooding is inevitable.

Did you know?

Green roofs have existed for centuries. The Vikings used grass sods on the roofs of some of their buildings. Modern buildings use a more high tech approach, with impermeable base layers, and drainage and irrigation systems.

Hard and soft engineering

Urban drainage has long been established as an engineering challenge. Sewerage and water treatment plants will always be required for the safe management of human waste and industrial effluent. However, similar *hard-engineering* approaches to surface water drainage are no longer assumed to be the only solution. Simply transferring water to the nearest river necessitates management if its capacity is not to be overwhelmed (section 3.17). Hard-engineering projects invariably involve high costs of construction and also ongoing maintenance. They also require long periods of planning – not least to determine their social, environmental and economic impacts. So *soft-engineering* approaches, working with, rather than against, natural processes are increasingly adopted as more affordable, sustainable solutions (Figure **1**). Also see *AQA Geography A Level & AS Physical Geography*, 3.9.

Hard engineering	Soft engineering
River straightening involves cutting through meanders to create a straight channel. This increases the gradient and speed of flow which may increase flood ris k further downstream. In some places the straightened sections are lined with concrete (see *channelisation* below).	Afforestation (planting trees to establish woodland or a forest). Trees increase interception and reduce throughflow and surface runoff because they take up water to grow. In short, evapotranspiration from both leaves and branches dissipates water that would otherwise end up in the river channel.
Natural levées can be made higher, so increasing capacity. *Embankments* are raised riverbanks using concrete walls, blocks of stone or material dredged from the river bed. The latter is arguably a more sustainable, environmentally friendly option and looks more natural than the concrete walling more common in urban areas.	*Riverbank conservation* by planting bushes and trees reduces lateral erosion, bank collapse and so silting-up of the channel. This is because their roots stabilise the banks by binding the loose material/sediments together.
Diversion spillways (flood relief channels) by-pass the main channel. They can be for emergency use only (controlled by sluice gates) when high flow levels threaten flooding or a permanent feature enhancing the environment by creating new wetlands and recreational opportunities.	*Floodplain zoning* restricts different land uses to certain locations on the floodplain (e.g. nearest the channel may only be used for pasture or for recreational use). Natural floodplains act as a natural soakaway, so protecting them from development and reducing surface runoff into the channel.
River *channelisation* involves lining straightened channels with concrete. This reduces friction, improves the rate of flow and reduces the build-up of silt because it prevents the banks from collapsing. But, channelisation looks unsightly and damages local ecosystems.	*River restoration* involves a return of the channel to its natural course and so reversal of artificial drainage management 'solutions' adopted in the past. This return to nature is discussed in 3.19.

Figure 1 *Contrasting drainage management approaches*

Sustainable Drainage Systems (SuDS)

Sustainable Drainage Systems (SuDS) represent the ultimate in realistic, yet environmentally friendly, replication of natural drainage systems within any built environment. (The acronym has stuck even though the 'urban' has been removed because the techniques can be adopted in all urban or rural developments whether housing, industrial, commercial or transport.) They hold back and slow surface runoff from any development and allow natural processes to break down pollutants.

Techniques

SuDS techniques include:

- swales – wide, shallow drainage channels that are normally dry (Figure **2**)
- permeable road and pavement surfaces – use of porous block paving and concrete (Figure **3**)
- infiltration trenches – gravel filled drains and filter strips
- bioretention basins – gravel and/or sand filtration layers beneath reed beds and other wetland habitats to collect, store and filter dirty water (and provide a habitat for wildlife)
- detention basins – excavated basins to act as holding ponds for water storage during flood events
- rain-gardens – shallow landscape depressions planted with flowers and shrubs
- green roofs – super-insulating wildflower habitats with minimal runoff to gutters.

Figure 2 *Swales can be landscaped as attractive community spaces.*

Benefits

The benefits of SuDS are remarkable in:

- slowing down surface water runoff and reducing the risk of flooding
- reducing the risk of sewer flooding during heavy rain
- preventing water pollution
- recharging groundwater to help prevent drought
- providing valuable habitats for wildlife in urban areas
- creating green spaces for people in urban areas (Figure **2**).

Figure 3 *Permeable through-draining car park. The blocks have a 5 mm gap filled with grit allowing water to soak away into the ground below.*

Lamb Drove, Cambourne

Look at Figures **4** and **5**. Lamb Drove in Cambourne, west of Cambridge, is an award-winning one hectare Cambridge Housing Society development of 35 'affordable' homes. Cambridgeshire is a relatively low-lying county where flooding in river valleys and urban watercourses is a major concern. The project was part of a European-funded programme (FLOWS), which featured 40 projects throughout Germany, the Netherlands, Norway, Sweden and the UK.

The original aim of the Lamb Drove SuDS scheme was to:

Figure 4 *Detention basin, Lamb Drove, Cambourne*

- showcase practical and innovative sustainable water management techniques within new residential developments
- demonstrate that SuDS are a viable and attractive alternative to more traditional forms of drainage and to deliver practical solutions for new housing areas.

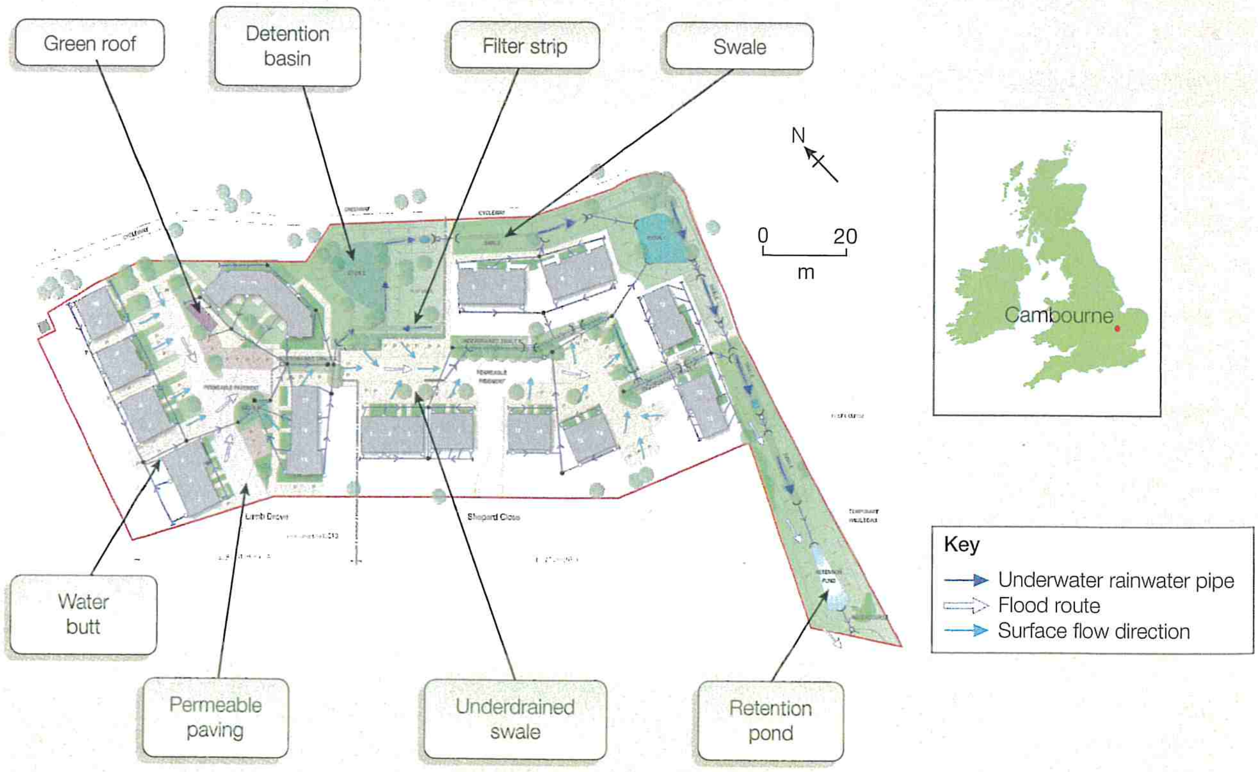

Figure 5 *Final design of the Lamb Drove, Cambourne SuDS scheme*

A range of SuDS components were used to demonstrate different available techniques and the application of a management train (see below) from prevention to site control and regional control components. The measures include:

- water butts to collect roof water for garden irrigation
- permeable paving allowing water to enter porous storage zones and to filter out pollutants.
- a green sedum roof to reduce and treat runoff
- swales (shallow open channels) to collect all excess water from the site, further slowing the flow and continuing the water treatment process
- creation of detention basins and wetlands in open spaces to slow down the runoff rate and store water on a temporary short-term basis during extreme (flood) events (Figure **4**)
- a retention pond for final storage of water before being released to a drainage ditch beyond the development site.

The developers adopted the concept of a *management train* at the site. This uses simple, natural and visible drainage components in series to improve the water quality. A management train also controls the quantity of runoff incrementally by reducing flow rates and volumes. In short, water management was considered from the point at which it falls on land and buildings to the point at which it leaves the site – so mimicking as much as possible the natural pattern of drainage prior to development. Roofwater that is not collected in water butts flows directly to grass swales or under-drained swales where pollutants (including heavy metals) are filtered. Rain falling on roads or paths passes through the permeable block paving, again where it is filtered and stored in the permeable layer of crushed rock below.

As such, the management train has water travelling downstream through a series of swales, detention basins and wetlands until it reaches the final retention pond.

The project is a proven success having been monitored and appraised ever since its completion in 2006. Concerns that standing water might prove to be a hazard have proved unfounded. Furthermore, it is cost-effective – both construction and ongoing maintenance costs have been 10 per cent less than conventional pipe drainage systems. There has also been a substantial improvement in the biodiversity, ecology and subsequent quality of life at Lamb Drove compared to typical residential developments. For example, the sculptured swales and detention basins have resulted in a visually enhanced and attractive landscape providing an increased amenity and social value to both residents and the local community. The use of SuDS has also resulted in an improved quality of water leaving the site compared with traditional piped drainage systems.

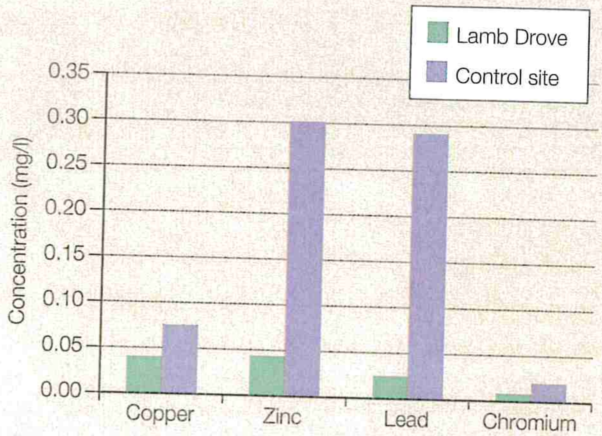

Figure 6 *A comparison of heavy metal concentrations at Lamb Drove, Cambourne and a nearby control site*

ACTIVITIES

1. Study Figure **1**. Critically assess hard- and soft-engineering solutions to urban drainage management.
2. Study Figures **5** and **6**.

   Explain why the Lamb Drove development is now cited as 'best practice' for all planners nationally. Consider social, economic and environmental costs and benefits.

STRETCH YOURSELF

SuDS could be described as a hybrid of hard- and soft-engineering drainage techniques. Discuss this point of view.

Think about

It is worth considering whether or not SuDS systems are designed to reduce the impact that the surface water drainage system of one site has on other sites downstream, rather than reducing flooding on the development site itself. In fact would it be appropriate to go as far to suggest that it is a misconception of SuDS systems that they reduce flooding on the development site?