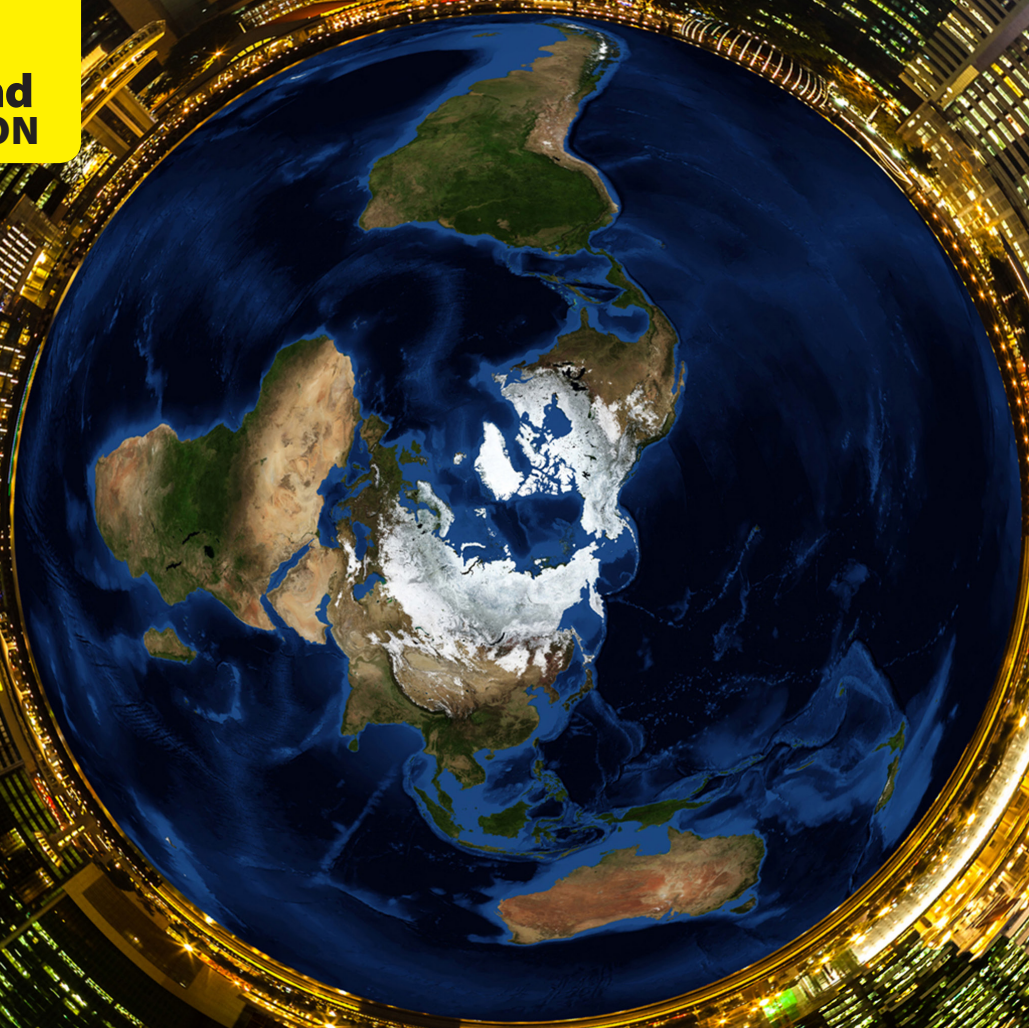
AS LEVEL

GEOGRAPHY

FOR CCEA AS LEVEL

2nd EDITION



Martin Thom and
Eileen Armstrong

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Rewarding Learning

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Print ISBN: 978 1 78073 107 0
eBook ISBN: 978 1 78073 293 0

Second Edition
Second Impression 2019

Layout and design: April Sky Design

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The author acknowledges her husband's contribution to the research, data collection and photographic material used in this book. She also acknowledges the help and support of the editorial and design staff in Colourpoint, Newtownards.

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Approved/endorsed by CCEA on 20 September 2016. If in any doubt about the continuing currency of CCEA endorsement, please contact Heather Clarke at CCEA, 29 Clarendon Road, Belfast, BT1 3BG.

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Unit AS 1:
Physical Geography

1A Processes that shape fluvial environments

"Everything has to do with geography."
Judy Martz

Case studies
General reference to places for illustration purposes only

Students should be able to:

- **(i)** explain how the drainage basin operates as an open system with inputs, outputs, stores and transfers of energy and matter
- **(ii)** understand storm and annual hydrographs (regimes) and explain the factors that influence them – relief, basin size and shape, soil, geology, land use, drainage density and precipitation
- **(iii)** understand river processes – erosion (abrasion/corrasion, attrition, hydraulic action, solution/corrosion), transportation (suspension, solution, saltation, traction), and deposition (Hjulström curves)
- **(vi)** explain the formation of river landforms – waterfalls, rapids, meanders, pools and riffles, oxbow lakes, levées, floodplains and deltas (arcuate and bird's foot)

Few subjects touch the world in which we live quite like Geography. Listen to any news bulletin and topic after topic relates to some aspect of this multidimensional subject. So all-embracing is Geography that it defies easy definition, leaving some to state: "Geography is what Geographers do". This textbook, like the AS specification on which it is based, attempts to illustrate the unity in diversity of the subject. While its structure reflects three aspects of both physical and human geography, the overall theme is of interaction and understanding of the world through skills.

Seeing the world geographically – a systems approach

Making sense of the world has been a universal goal across time and space. The need to create order from the night sky initially led to the identification of patterns and constellations representing earth-bound items: lions and ploughs or mythical wonders, gods and giants.

One approach to unifying the study of geography is known as **systems theory**. In essence this is simply a pattern or framework through which aspects of the world can be viewed.

As illustrated (Figure 1) a system exists where a number of objects are linked by interactions between them. The objects are known as **stores** and the interactions as **transfers**. To identify a system the starting point is to recognise its boundaries. A

computer has clear boundaries and even the most advanced computer needs input such as power and data to operate. A system is said to be **isolated** if nothing transfers in or out across its boundaries or **closed** if only energy can enter or leave it. Most natural systems are **open,** as both materials and energy enter (**input**) and leave (**output**) them. The whole universe and its numerous parts can be regarded as systems. This can help us simplify the world and aid our understanding of how it operates.

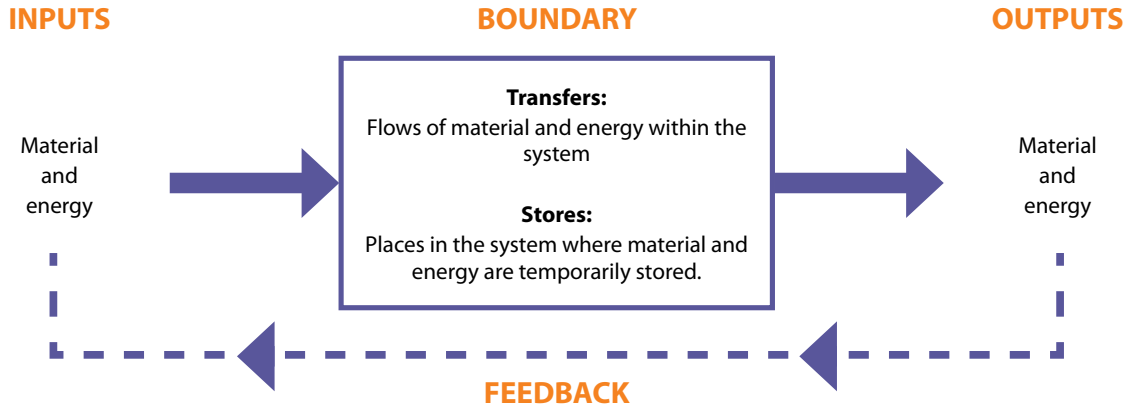


Figure 1: The elements of an open system

The drainage basin as an open system

Fluvial environments are those that result from the action of river processes.

The area of land that gathers water for a river is known as a **drainage basin**. The land boundary of a drainage basin is its **watershed** – an area of higher ground separating drainage down one slope from another. When **precipitation** (rain, hail or snow) falls from the atmosphere onto the land it must either return to the air (evaporate), sink into the ground or flow over the surface. The vegetation, ground surface, soil, underlying rocks and river channels are all **stores** in the basin. Infiltration, overland flow, through flow and groundwater flow are some processes or **transfers** within the basin system. Transfers of energy and materials across the system's boundaries may be either **inputs** – including precipitation and potential energy – or **outputs** – such as evapotranspiration and runoff (Figure 2). Most natural river networks have many **channels** that join together as **tributaries** (contributing water) to form larger rivers and drainage basins.

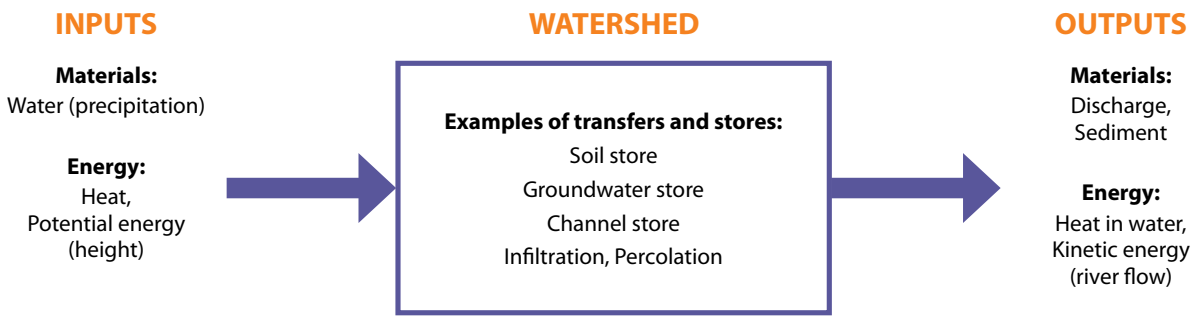
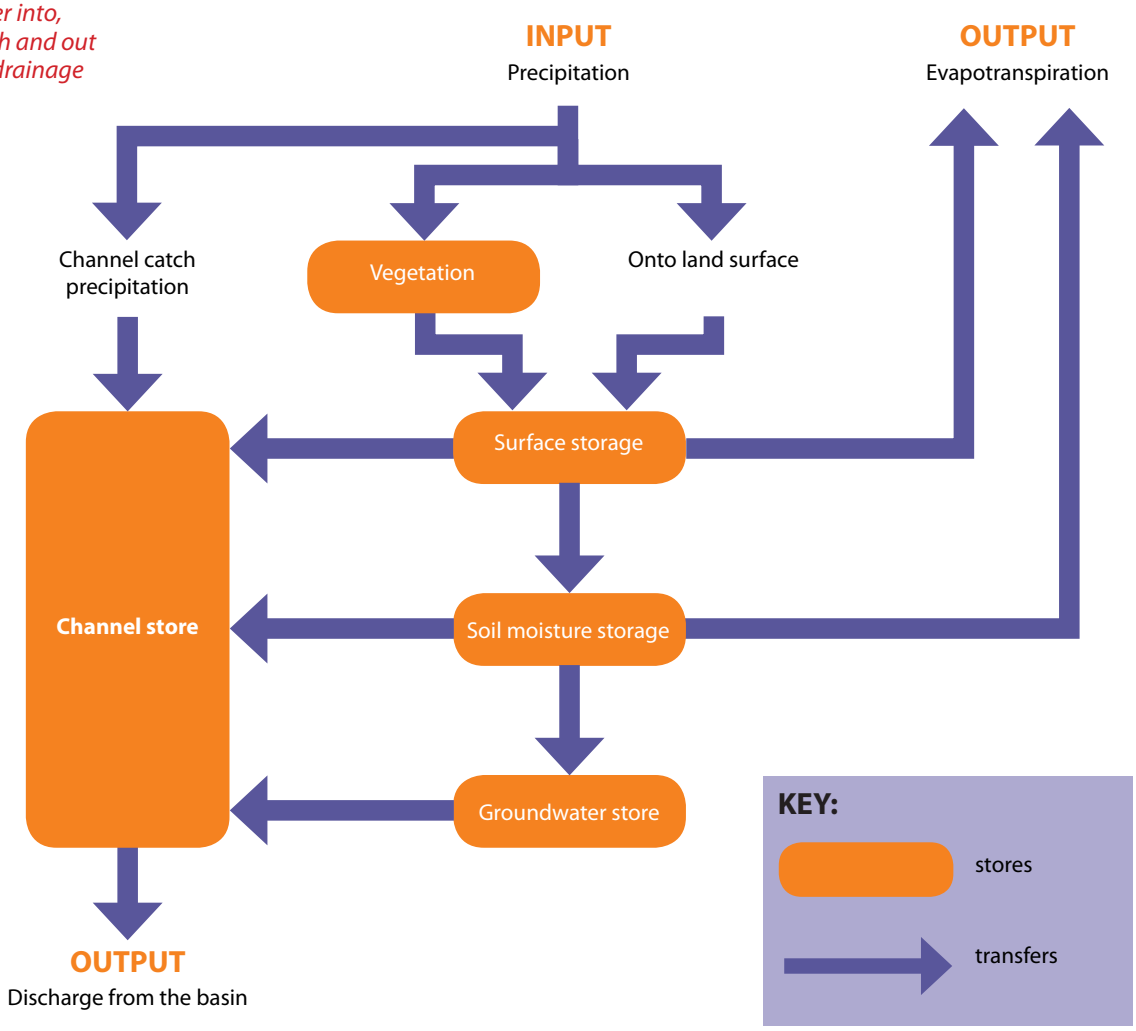


Figure 2: The drainage basin as an open system

While water is the most obvious component that moves in, through and out of a drainage basin open system, there are others including sediment and energy (heat and potential energy). Figure 3 outlines the transfers of water across the boundaries of a drainage basin and between its stores.

Figure 3: Movement of water into, through and out of the drainage basin



Processes in a drainage basin

1. Surface flows and outputs

Precipitation may enter a drainage basin directly into the river itself (channel catch), onto the land surface, or caught on the vegetation (interception). Once it reaches the surface, water may be lost to the system by evaporation or it may move across the land (surface runoff or overland flow) or into the soil (infiltration). Once in the soil, water may be taken up by plant root systems and ultimately lost through leaves back to the air (transpiration). The output from a drainage basin into the atmosphere is termed **evapotranspiration**. Water that flows over the land will gather in the river channels at the base of slopes.

2. Infiltration and subsurface flows

One of the key factors in how a river basin responds to rainfall is the movement of water into the soil and through the soil and groundwater stores. Soil is mostly made of inorganic particles (rock fragments) of various sizes, from fine *clays* through medium

silt-sized to large *sand-sized* material. The exact mixture of these particles in a soil is described as the **soil texture** (Figure 4).

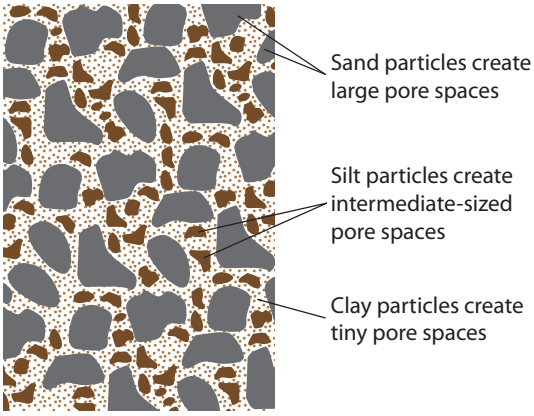


Figure 4: Illustration of pore space in a soil with mixed texture

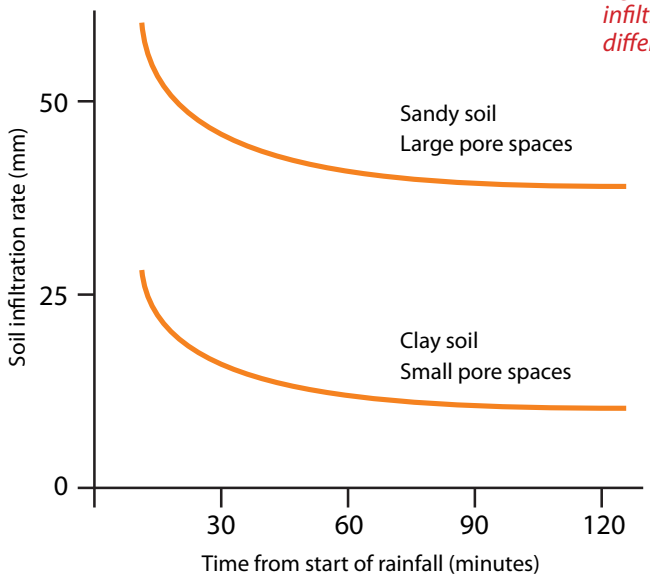
Soil particles are separated from each other by small spaces or pores. It is through these that water can:

- infiltrate from the surface into the soil.
- percolate from the soil down into the underlying rock.
- through-flow downslope within the soil.

Different soils have different rates of infiltration, for example, sandy soils have large pores and water moves in quickly. This characteristic is the soil's infiltration rate and this is measured in mm per hour.

Soils that allow water to enter rapidly are described as **permeable** whereas **impermeable** soils, often clay-rich, allow water to enter only slowly. A key factor to note about infiltration is that the rate changes during the course of a rainfall episode (storm). As Figure 5 shows, no matter what soil type is found, the infiltration capacity is relatively high when rain starts. This is because the soil is dry and has pore space available, but the infiltration capacity falls to a lower, stable level as the pores fill up over time.

Figure 5: Typical infiltration rates for different soil types



The movement of water from the soil into the underlying rock is called **percolation**. Most rocks can store water either within the rock itself (porous), or within the cracks and joints they contain. This stored water is referred to as **groundwater** and it slowly makes its way into river channels as **groundwater flow**. The height of the groundwater level in rock is known as the **water table**. This underground source of water can maintain river flow even after weeks or months without rainfall. Remember river systems also transfer sediment as well as water.

Measuring and recording river flow

Discharge is the volume of water passing any one point in a given time. It is calculated by multiplying the channel's cross-sectional area (metres squared) by the river's velocity (metres per second). The units of discharge are therefore cubic metres per second ($m^2 \times m/s = m^3/sec$) or **cumecs**.

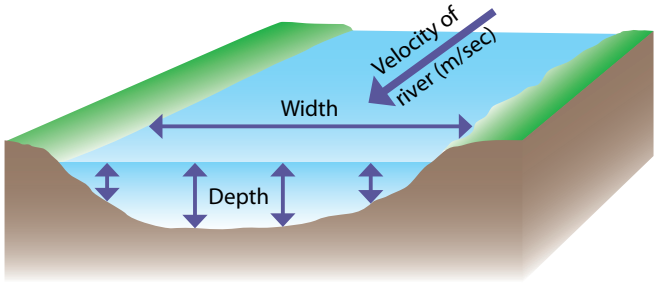


Figure 6: How to find the discharge of a river

The pattern of changing discharge at any point along a river can be plotted on a time/discharge graph called a **hydrograph**. An **annual hydrograph** would show the variation in river discharge over a year whereas a **storm** or **flood hydrograph** records the impact of one period of precipitation on water flow.

Annual hydrograph

A river system's annual hydrograph shows its variation in discharge over a year. Most usefully these can be averaged, over 30 years or more, to give the mean flow pattern (Figure 7). Just as the weather describes the day-to-day change of the atmosphere and climate describes the normal pattern of seasonal weather, the Annual Hydrograph, sometimes called a river's regime, illustrates the system's normal yearly flow pattern.

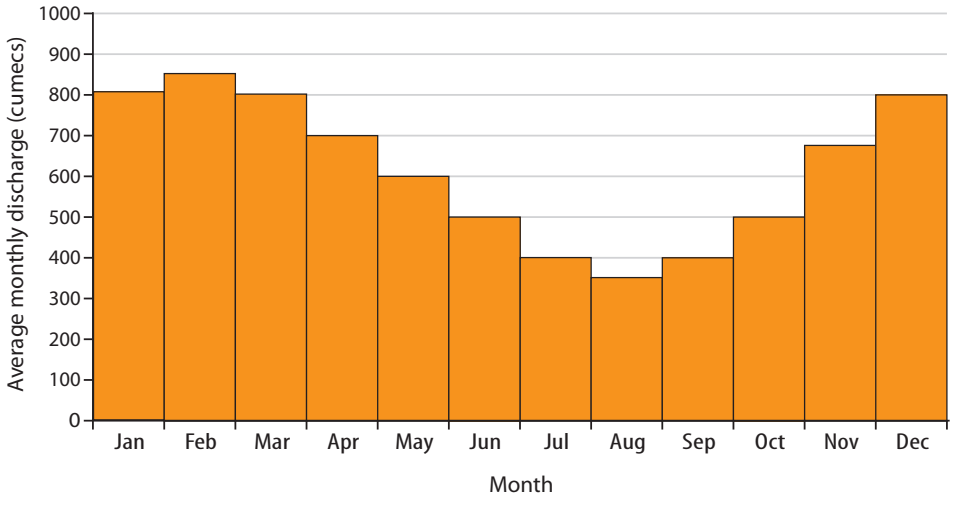


Figure 7: The annual hydrograph or regime of the River Severn

Events such as spring snow melt in mountain regions or the change between wet and dry seasons in the Asian monsoon lands will be reflected in the shape of annual hydrographs. Across much of Europe the river year is taken from the 1 October to the following 30 September. This is because rivers are normally at their lowest flow level in Europe around those dates.

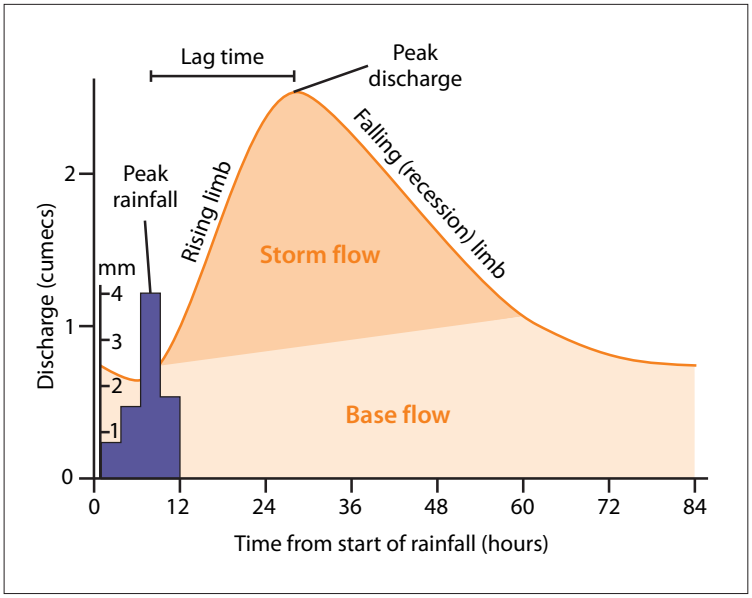
Why would this be likely to be true in the UK or Ireland?
Clue: It is not about the amount of precipitation it has more to do with other ways that water leaves (outputs) drainage basins.

Annual hydrographs are useful for planners when they are examining new developments or changing land use across a basin. They are also important for water engineers working to ensure an adequate year round water supply and prevent water shortages or floods.

Storm hydrograph

Figure 8 shows a model storm hydrograph, including the terms used to describe the line of changing discharge, and the area beneath the line that represents the total volume of channel flow. The superimposed bar graph shows the amount and pattern of precipitation (storm) that causes the subsequent changes in flow. Two sets of transfers within drainage basins impact the shape and nature of a hydrograph: firstly, the **fast (surface) flow** processes of channel catch and overland flow; and secondly the **slow (sub-surface) flows** of through flow (soil) and groundwater (rock) flow.

Figure 8: Model hydrograph of storm flow



A typical storm hydrograph follows a sequence. After rainfall commences, some falls directly into the channel and discharge rises, but much of the rain falls on the basin and may infiltrate into the soil. Eventually the soil becomes saturated, or if the rainfall is intense and exceeds the soil's infiltration capacity, water will flow over the surface as overland flow and quickly reach the channel. This accounts for the initial increase in discharge shown as the **rising limb**.

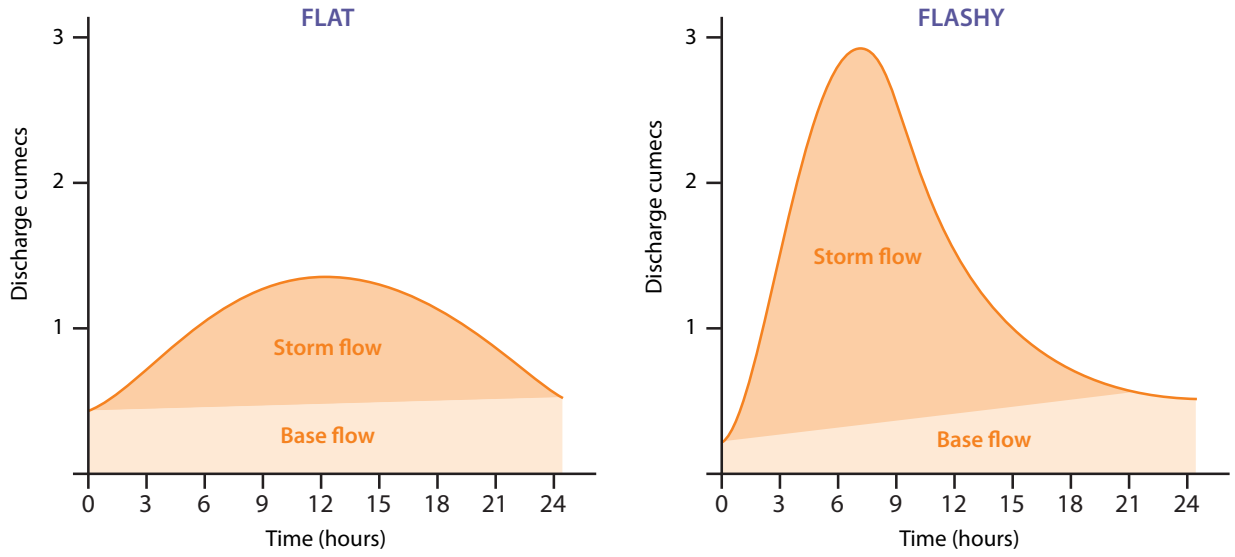
Even in small drainage basins it takes time for water to make its way to the channel and this delay between the **peak rainfall** (bar graph) and the **peak discharge** (hydrograph) is called the **lag time**, and may be measured in minutes or days depending on size of the drainage basin.

The peak discharge is a critical point because if it higher than the carrying capacity of the river channel, flooding will occur. Following the peak discharge is the **falling** or **recession limb**, where the remaining water from the storm period moves from the basin. The hydrograph levels out at a lower level but flow continues as a slow transfer from the groundwater store feeds the channel. This 'background' flow is called **base flow**, while **storm flow** refers to the discharge that resulted from the period of precipitation involved.

In general terms the shape of hydrographs varies between two extremes:

- A wide, shallow curve with gentle rising and recession limbs, and a low peak discharge following a long time lag. This is known as a **flat response**.
- A steep-sided, rapidly changing graph with a high peak discharge and a short lag time. This form is known as a **flashy response** and often brings the threat of river flooding.

Figure 9: Hydrograph shapes



Characteristics	
• Gentle limbs	• Long lag time
• Low peak discharge	• Significant base flow
• Long storm flow	• Flooding unlikely
Environment	
• Permeable soil and rocks	• Forestry

Characteristics	
• Steep limbs	• Short lag time
• High peak discharge	• Small base flow
• Short storm flow	• Flooding likely
Environment	
• Impermeable soil and rocks	• Urbanisation of surfaces and drainage system

Factors affecting basin discharge and the storm hydrograph

The way that a basin responds to rainfall, as shown by its flood hydrograph, depends on many different factors. These can be classified in two groups: 1. the nature of the storm or 2. the nature of the drainage basin.

1. Nature of the storm

A period of precipitation has many variables, all of which can influence how drainage basins deal with the input. How long the storm lasts, how heavy the storm is, the type of precipitation (rain, hail, or snow) or even the direction and speed of the rain storm across the basin will all impact on the hydrograph shape. It is fair to say that no two storms are identical.

Try to imagine how each of these factors would change the appearance of the storm hydrograph. What would be the impact of a long period of light rain compared to an intense short but heavy storm? Would the impact of identical storms be different if one took place in February and the other in August? In your answers use as many of the hydrograph terms as possible.