Geo Factsheet

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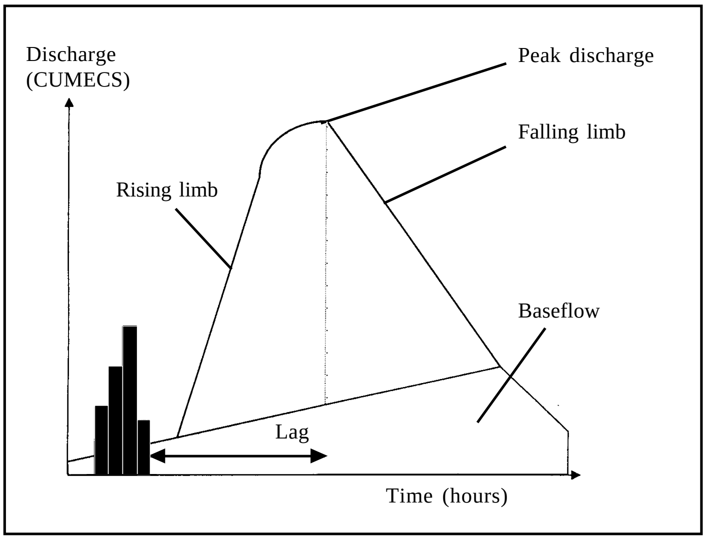
Storm Hydrographs

Exam questions on storm hydrographs are frequently set, as they let examiners test understanding of many aspects of hydrology. Candidates need to know how climate, rock type, vegetation, basin characteristics and human activity affect river discharge. The best candidates will also be able to support hydrological theory with reference to a real drainage basin.

The storm hydrograph (Fig. 1) is a graph on which river discharge (y-axis) during a storm, or single precipitation event, is plotted against time (x-axis). Discharge is the volume of water flowing through a cross-section of river during a given time period. It is usually measured in cubic metres per second (cumec). To interpret a storm hydrograph, a geographer needs a clear understanding of the influence of the factors which affect the volume, and timing of river discharge.

Fig 1. A Model Storm Hydrograph



The first stage of a storm hydrograph shows discharge before precipitation. From the beginning of the storm, river discharge rises until it reaches a peak. The time period between the end of rainfall and the peak of discharge is called the **lag time**. The rising limb is the period during which discharge increases. The descending limb is the period during which discharge decreases. The rising limb is always steeper than the descending limb.

Hydrograph separation (Fig 2.)
The interpretation of the storm hydrograph starts with hydrograph separation.

1. Direct channel input - a very small amount of rainfall falls on the river itself.

2. Interception - water falls on to vegetation and non-living surfaces before it reaches the ground. This water may reach the ground by stemflow and drip or it may evaporate.

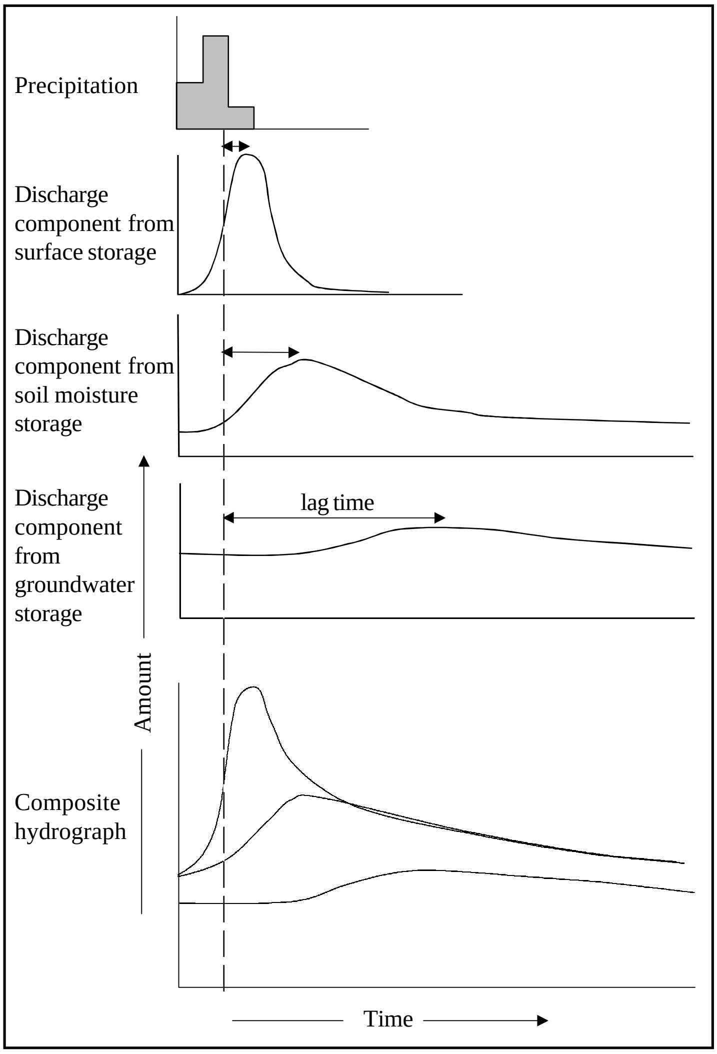
3. Infiltration - when water reaches the ground surface it is absorbed into the soil through pores. The speed at which water is absorbed by the ground, or infiltration rate, is highest for grassland and lowest for bare soil and rock.

4. Percolation - water in the soil moves downwards into the aquifer. The aquifer is the zone of saturated rock. The uppermost level of saturation, or water table, can vary in depth over time.

The rainwater may then reach the river channel in several ways:

1. Overland flow - rainwater which flows over the ground surface. There are two types of overland flow. **Infiltration-excess overland flow** occurs when the rain is falling more quickly than the infiltration rate. In the U.K., it is more common in summer. **Saturation-excess overland flow** occurs when soil spaces are so full of water that no more rain can be absorbed. In the U.K., it is more common in winter. Surface runoff is the fastest way in which water can reach the channel.

Fig 2. Hydrograph Separation



2. Throughflow - rainwater which has infiltrated into unsaturated soil can move horizontally to the river channel. This process is slower than overland flow but faster than baseflow.

3. Baseflow - rainwater which has percolated to the aquifer can seep into the river channel. This is the slowest process.

The level of discharge before the storm is called the **antecedent discharge**. In summer, when there has been little precipitation, antecedent discharge is small. In winter, when there has been heavy continuous precipitation, antecedent discharge is much higher. Even a small amount of rain can lead to flooding.

When the rain begins, the changes in discharge are very small because little rain falls on the channel itself. Most of the discharge will have reached the channel by baseflow. Baseflow responds very slowly to precipitation inputs.

As the discharge builds up, a larger proportion is throughflow. Near to peak discharge, a significant proportion of the water will have reached the channel by overland flow. After the peak discharge has passed, the descending limb is less steep because discharge no longer contains any element of surface runoff. The discharge returns to baseflow level.

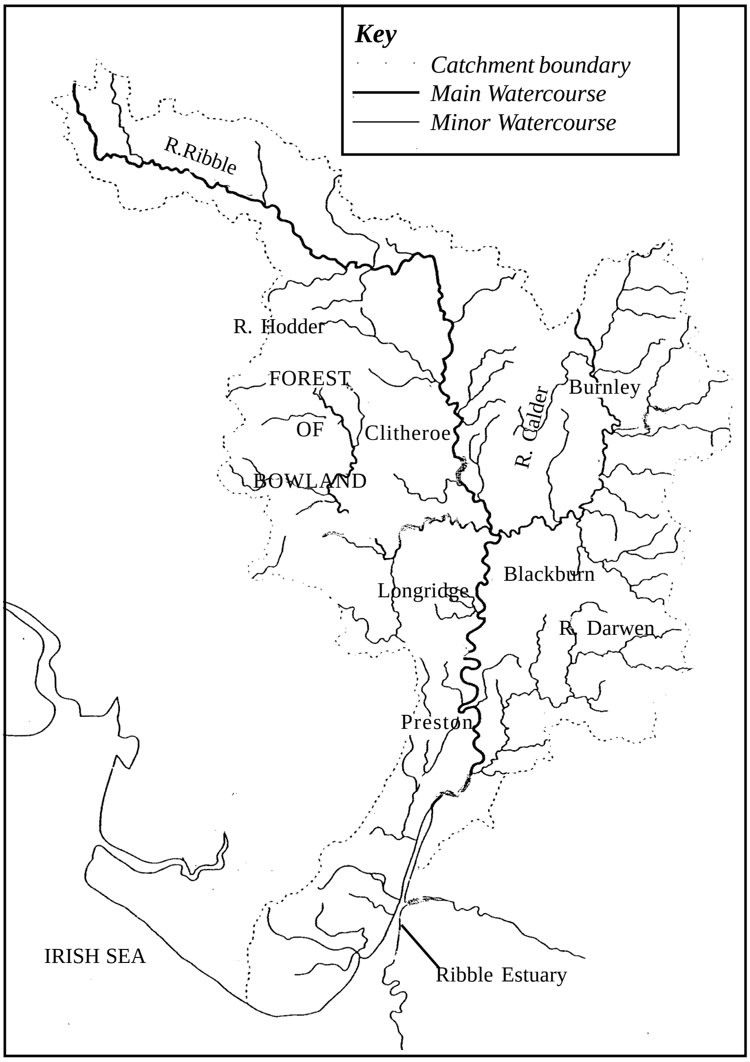
Table 1. Identification of hydrograph controls

Hydrological Factor	Effect on the shape of the Storm Hydrograph	Reasons
Size of drainage basin	Lag time is shorter and peak is higher in a small basin compared to a larger basin.	Water reaches the channel more rapidly in a smaller basin as water has a shorter distance to travel.
Shape of drainage basin	Lag time is shorter and peak is higher in a more circular basin than a more elongated basin.	It takes less time for water to reach the channel in a circular basin as all extremities are roughly equidistant from the channel.
Relief	Lag time is shorter and peak is higher in a steeper basin.	Water reaches the channel more rapidly in a steeper basin as water is travelling more quickly downhill.
Length of precipitation event	Lag time is shorter and peak is higher after prolonged precipitation.	The ground is saturated with water, so there is more saturation-excess overland flow.
Intensity of precipitation	Lag time is shorter and peak is higher after intense rainfall.	Where rain is falling faster than the infiltration rate there is infiltration-excess overland flow. This is common after a summer storm.
Type of precipitation	Lag time is slower and peak is lower after snowfall.	Snow does not reach the channel but is stored on the ground surface. As snow melts, the meltwater will reach the channel quickly as infiltration is impeded if the ground is still frozen.
Permeability of rock type	Lag time is shorter and peak is higher in an area of impermeable rock type.	Impermeable rocks are saturated more quickly than porous and pervious rocks. Saturation-excess overland flow is more common.
Vegetation	Lag time is slower and peak is lower in a forested basin.	Vegetation intercepts a large proportion of rainfall. Where trees are deciduous, discharge is higher in a forested basin in winter as there is less interception.
Soil texture and structure	Lag time is slower and peak is lower in areas of sandy soil.	Sandy soils have larger pore spaces than clay soils. Infiltration is most rapid in sandy soils.
Urbanisation	Lag time is faster and peak is higher in an urbanised catchment.	Surface runoff is higher in urban areas because there are more urban surfaces (concrete and tarmac) and sewers take water rapidly to rivers.
Deforestation	Lag time is faster and peak is higher in a deforested catchment.	There is less interception and evapotranspiration and more surface runoff in a deforested catchment.

Case Study: River Ribble, Lancashire, U.K.

The River Ribble is 110 km long and drains a basin of 2182 km^2 (Fig. 3). It rises high in the Pennines at 442 m above sea level. The river flows southwards then westwards before joining the Irish Sea at Preston.

Fig 3. Drainage Basin of the River Ribble



During intense storms, the Ribble's hydrograph has a short lag time and a high peak of discharge. Both the rising and descending limbs are rapid. However, after continuous rainfall, the river can absorb large quantities of water without major flooding. What factors cause this pattern of discharge?

- *Rock types - the upper course of the Ribble and its tributaries drain areas of Millstone Grit and Carboniferous limestone. The Millstone Grit is formed of densely packed sand particles with very few pore spaces. Overland flow is rapid as the rock is impermeable. The limestone has joints and bedding planes which have been widened by weathering. Throughflow reaches the river channel quickly. Most areas are covered with glacial drift. As this is largely unconsolidated, with few large pore spaces, overland flow is fast.*

- *Soil types - the upper course contains large areas of peat soils. It is a major store of groundwater. Peat can slow down the increase in discharge.*

- *Shape and size of drainage basin - the basin is elongated. It takes more time for water to reach the channel in a long basin. The basin is also one of the largest in the northwest of England. Flooding in the upper basin, past bankful discharge, increases friction and reduces the velocity of water. There are extensive flood plains in the upper river, formed before the river was rejuvenated as a result of isostatic sea-level fall.*

- *Rainfall - rainfall varies from 1775 mm at the river's source to 890 mm at the estuary. The rainfall is evenly distributed throughout the year. Infiltration-excess overland flow is most common after intense summer thunderstorms. Saturation-excess overland flow is more common in late winter, although the peat can store large quantities of water.*

- *Urbanisation - a major tributary, the River Calder, flows through heavily urbanised areas such as Burnley. Discharge is rapid because water is directed into the river by storm drains and runoff from concrete and tar surfaces. However, the Calder does not contribute much to flooding in the Ribble because its basin is circular.*

- *Agriculture - some farming practices in the Forest of Bowland, the basin of the tributary River Hodder, contribute to flooding in the lower Ribble. Overstocking with sheep, often on steep and marginal land, has led to degradation of vegetation cover. Soil has been exposed to erosion, leading to gullying and faster overland flow. The burning of heather for grouse shooting is not always properly managed. On some moors, the peat cover has been lost and surface runoff is encouraged.*

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Practice Questions

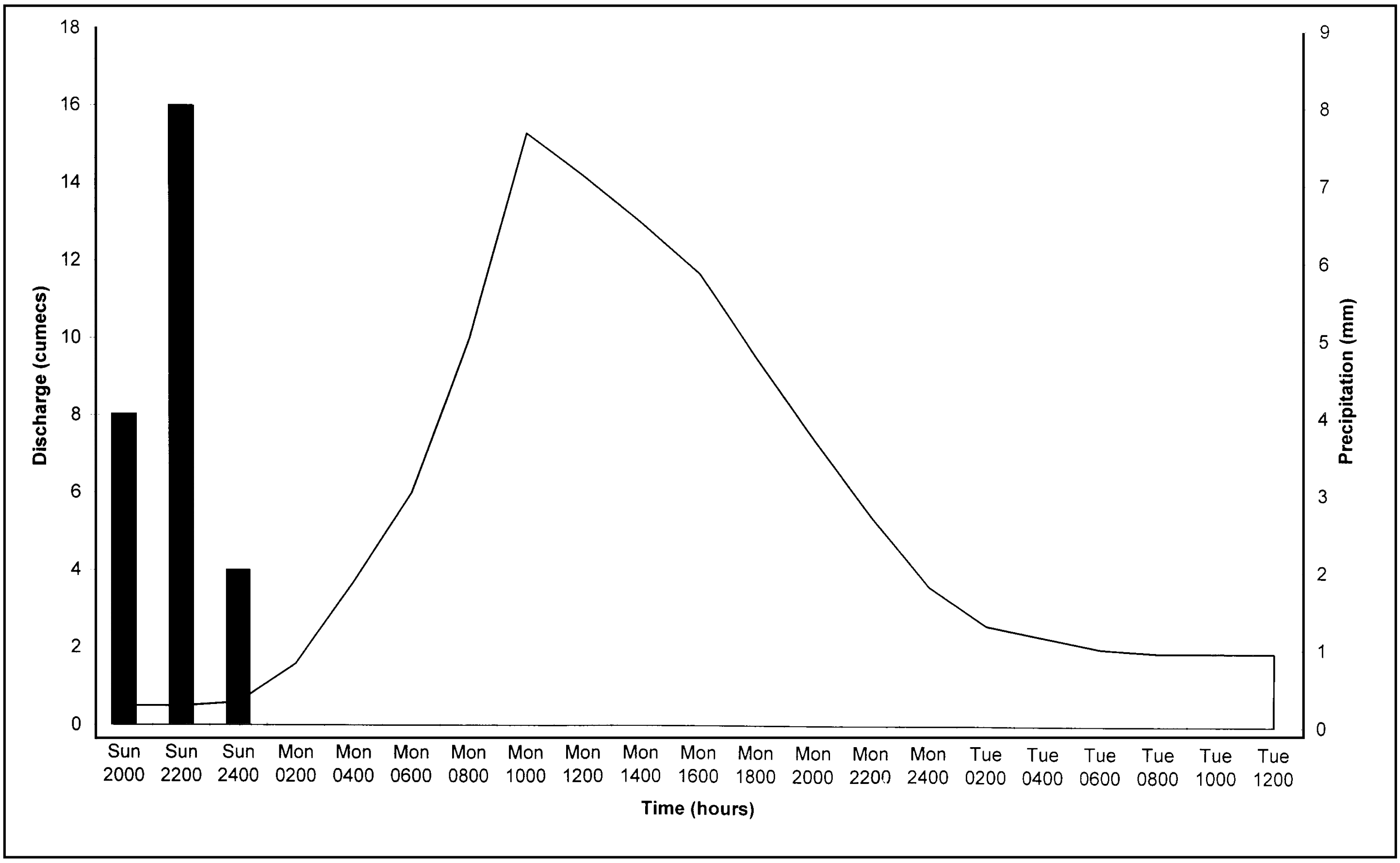
Fig 4. shows the storm hydrograph for the River Brathay in Cumbria over 40 hours in January. The River Brathay has a small, round drainage basin with steep slopes and podsolic soils. This storm occurred after a week of heavy rainfall.

(a) Describe the changes in precipitation and discharge; (4 marks)

(b) Explain the changes in discharge which took place on:
  (i) Monday a.m. (3 marks)
  (ii) Monday p.m. (3 marks)

(c) Explain:
  (i) how human activities can reduce discharge; (5 marks)
  (ii) how human activities can increase discharge. (5 marks)

Fig 4. Storm hydrograph for River Brathay (Cumbria)



Answers

Semicolons indicate marking points

(a) 14mm of precipitation falls from Sunday 2000 to Monday 0200; no precipitation from Monday 0200 to Tuesday 1200; discharge increases from 0.5 cumecs at Sunday 2200 to 15.3 cumecs at Monday 1000; discharge falls from 15.3 cumecs at Monday 1000 to 1.9 cumecs at Tuesday 0800.

(b) (i) The rising limb is steep and the lag time is short because rainwater reaches the channel by overland flow. After a week of heavy rainfall, the soil would be almost saturated with water. Only a small amount of rainfall is necessary to cause saturation-excess overland flow. The steep slopes and low rate of soil infiltration in podsols lead to rapid infiltration-excess overland flow. Since the basin is small and round, precipitation reaches the central river Brathay quickly.

(ii) The descending limb is less steep than the rising limb. Discharge at this stage contains a large proportion of throughflow. The river recovers rapidly because most of the precipitation was carried to it as overland flow. There is relatively little throughflow or baseflow because the soils are impermeable.

recovers rapidly because most of the precipitation was carried to it as overland flow. There is relatively little throughflow or baseflow because the soils are impermeable.

(c) (i) Humans can extract water, either directly from rivers or indirectly from boreholes. Water can be used for public water supplies, irrigation of crops or industrial processes. River extraction reduces the discharge directly. Borehole extraction reduces the level of the water table and the amount of throughflow and baseflow. Low flow can also be reduced by a loss of soil and rock storage by urbanisation. Less water infiltrates the soil or percolates into the bedrock. Humans can use reservoirs to store water which would otherwise cause floods. Afforestation reduces the rate at which water reaches the channel.

(ii) Humans can add water in sewage-plant, drain or industrial effluent. Inter-basin water transfer increases discharge. Water can be released from storage reservoirs to maintain low flows. Rapid overland flow from impermeable urban surfaces increase the size of storm discharge. Deforestation increases the speed of the onset of overland flow by reducing interception. The water storage capacity of vegetation is lost.