Drainage basin characteristics

The nature of the drainage basin affects the way water moves through it. Interception, infiltration and percolation all impact on the amounts of overland flow, throughflow and baseflow. These, in turn, determine the speed at which water moves through the drainage basin to the river. The rate at which water arrives at the river affects river discharge.

Size and shape of the drainage basin

Basin size is important. Smaller drainage basins collect less rainfall than larger basins and the discharge of their rivers is smaller as a result. Smaller basins also respond more rapidly to inputs of rainfall. In 2004, heavy rain fell on the small drainage basin that includes Boscastle in the UK. The basin responded so rapidly that the flash floods gave people no warning and no time to prepare. Basin shape also affects flooding. Circular basins respond more promptly to rainfall inputs and have a higher discharge than long, narrow basins of a similar area.

Drainage density

This is the total length of surface streams per square km. It is related to the infiltration rate. Basins with low infiltration have more overland flow and a higher **drainage density** than basins with high infiltration. As a result, drainage basins with a high drainage density respond more quickly to inputs of rainfall so they have rapid surface run-off and a rapidly rising, high discharge.

Soil and rock type

A drainage basin with impermeable soil and bedrock will have a great deal of overland flow but less throughflow and baseflow. Because overland flow is a much faster process than the other two flows, this sort of basin will have higher discharge. A drainage basin with permeable (or porous) soil and bedrock will have much more infiltration and percolation, so throughflow and baseflow (groundwater flow) will be more important than overland flow. This will result in lower river discharge because throughflow and baseflow are much slower than overland flow. Baseflow from the large groundwater store in a basin with permeable rock will also keep the summer discharge relatively high, reducing seasonal variations in discharge.

Permeable rocks allow water to pass through them for different reasons. Granite and limestone contain tiny cracks, mostly vertical joints and horizontal bedding planes. Water can percolate down through these rocks along the cracks and we call these rocks *pervious* as a result. Chalk and Sandstone are made up of particles with pore spaces between the particles. Water can soak down through the pore spaces so these rocks are porous. Pervious limestone and porous sandstone are both permeable, in that they let water percolate down through them, but for different reasons.

Slopes

A drainage basin with steep slopes will have more overland flow and higher river levels than a basin with more gentle slopes where there is more time for water to infiltrate.

Vegetation type and land-use

Forests growing in a river basin tend to reduce the discharge of the river because forests increase interception, leading to greater evaporation. Forests also lead to increased transpiration, which also removes water from the basin before it can reach the river. Any land-use that creates impermeable surfaces or reduces vegetation cover tends to increase overland flow and river discharge. Pasture land allows rainfall to soak into the ground, but has less evapotranspiration than the forest it may have replaced, increasing river discharge. Floodplains tend to be fertile and are often used for arable farming which can involve the use of heavy machinery. These machines squash the soil, reducing infiltration, increasing overland flow and river discharge.

5. Explain how evapotranspiration influences river discharge.
6. Explain how overland flow, throughflow and baseflow affect river discharge.
7. 'Climatic factors are more important than drainage basin characteristics when explaining variations in river discharge'. To what extent do you agree with this statement?

Hydrographs – graphing the changes in river discharge

A graph showing how the river's discharge changes over time is called a **hydrograph**.

- A graph showing how a river's discharge changes over the course of one year is called an **annual hydrograph**.
- A graph showing how a river's discharge changes over a short period of time, responding to a single input of rainfall is called a **storm hydrograph**.

Each of these graphs can be used by hydrologists to help them understand the nature of a drainage basin and the factors that affect the discharge of its river. Water is a valuable resource so it is important to understand the river if its water is to be used sustainably. River flooding is an important hazard and if people are to manage flooding effectively, it is important to understand the way a river behaves and the factors that affect the changes in its discharge.

Annual hydrographs

Annual hydrographs are useful when hydrologists study the responses of a river to its environment. The following examples are all taken from the British Isles.

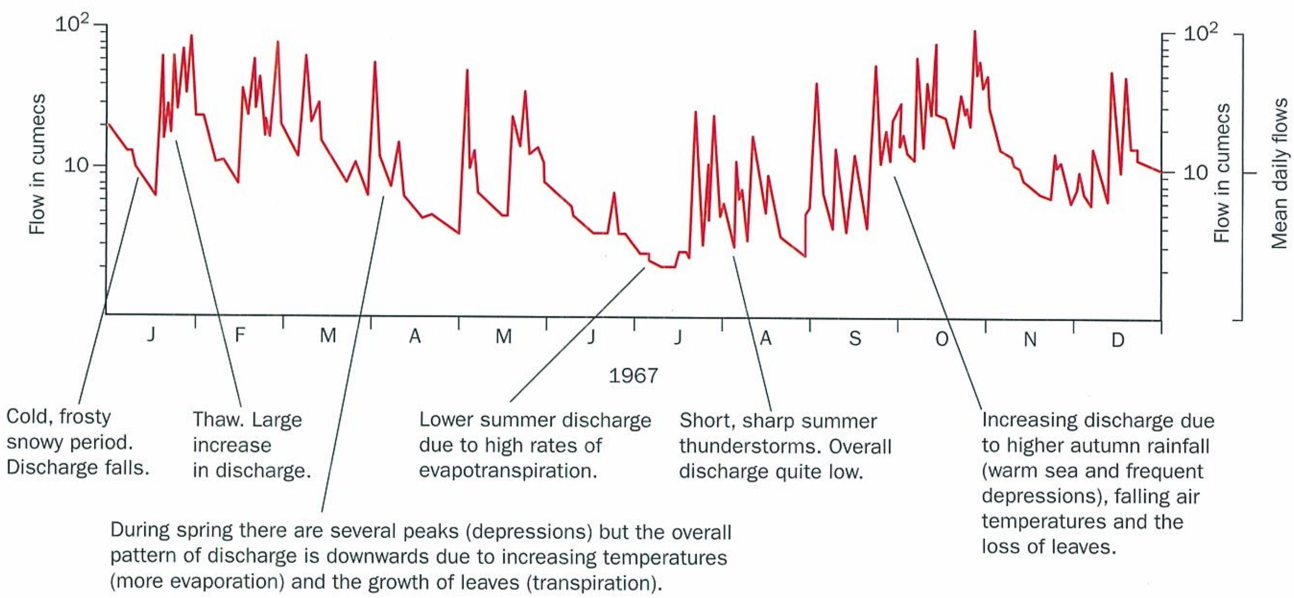

Fig. 1.9 River Dart annual hydrograph at Austin's Bridge, Devon, UK

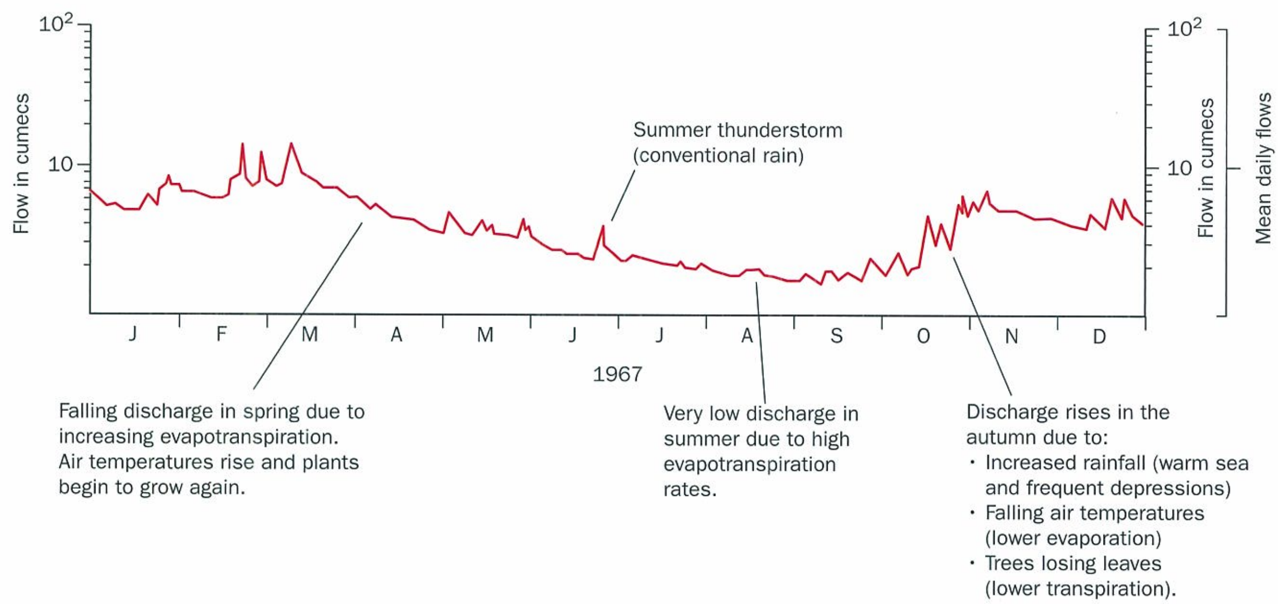

Fig. 1.10 River Avon annual hydrograph near Salisbury, Wiltshire, UK

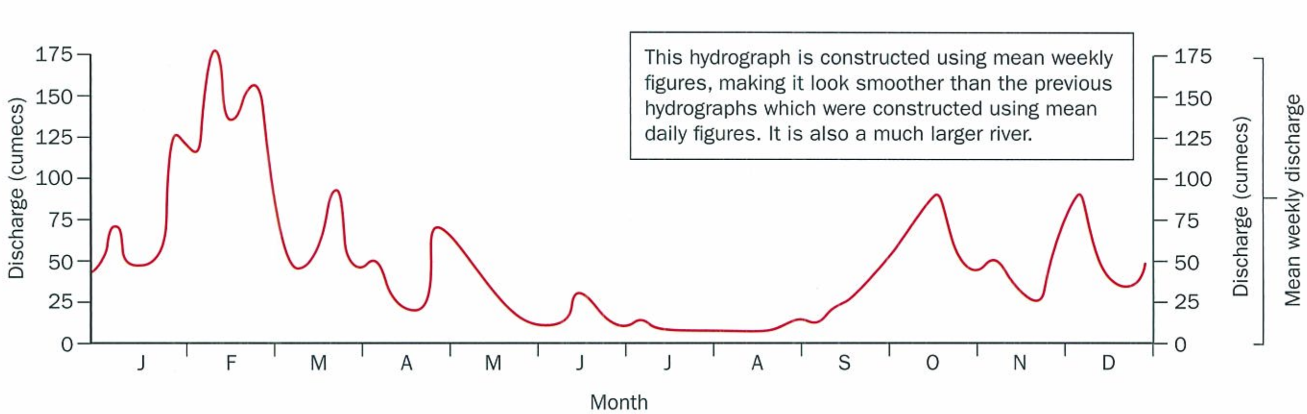

Fig. 1.11 River Severn annual hydrograph at Montford Bridge, Shropshire, UK

The River Dart is a short river that flows from Dartmoor in Devon. This is a very 'peaky' hydrograph, typical of rivers in western Britain. There is clearly a great deal of overland flow because the river responds quickly to the frequent inputs of rainfall. This river is likely to experience flash floods. The underlying reasons for the way that the River Dart behaves are as follows:

- high rainfall and frequent rainstorms, typical of hilly areas in western Britain
- impermeable soil and bedrock; Dartmoor is made of granite which encourages surface runoff at the expense of throughflow and baseflow
- a grass-covered drainage basin with very little forest to slow down and absorb rainwater.

The River Avon flows across Salisbury Plain, a chalk upland in southern Britain. This is a relatively smooth annual hydrograph with low and infrequent flood peaks. There is very little overland flow but a lot of baseflow. The river is responding to seasonal changes in rainfall and evaporation rates, rather than to individual rainstorms. Flooding is unlikely on this river. The underlying reasons for the way that the River Avon behaves are as follows:

- rainfall is relatively low in southern England
- permeable soil and bedrock; the bedrock is chalk, which is very porous and absorbs rainfall very easily. Throughflow and baseflow are much more important than overland flow because of the high infiltration rates. It might be supposed that this is a forested basin, but Salisbury Plain is actually mostly arable land or short grassland. It is the effect of the chalk bedrock which is the dominant factor affecting the discharge of this river.

8. Study Fig. 1.11.

(a) Describe the changes that take place in the discharge of the River Severn between January and August.

(b) Suggest reasons for these changes. You should consider precipitation, temperature, rock type, land-use and other possible factors. (The River Severn rises in the mountains of central Wales. Snowfall is common in the winter months.)

Storm hydrographs

How a drainage basin reacts to a large input of rainfall tells us about the nature of that drainage basin. We can then predict how it will react in future to similar rainstorms and make plans to cope with the perceived flood risk. The storm hydrograph is crucial here; it is the drainage basin's 'fingerprint'.

Definitions of some of the key words and phrases:

- *Discharge*: the amount of water in the river channel. It varies over time and it is the result of rainwater flowing into the channel via overland flow, throughflow and baseflow. In Fig. 1.12, the discharge responds to a large input of rainfall.

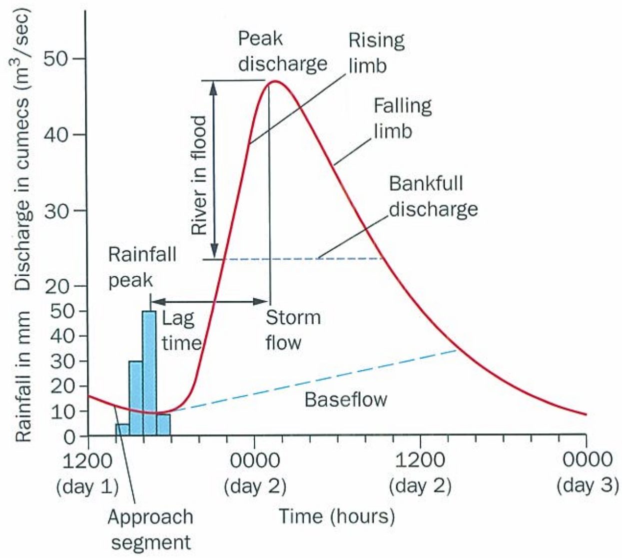

Fig. 1.12 A typical storm hydrograph

- *Cumecs*: cubic metres of water per second. The unit of measurement for river discharge.
- *Approach segment*: the discharge before the rainstorm.
- *Rising limb*: the discharge rises steeply after the storm, mostly due to overland flow.
- *Bankfull discharge*: when the river channel is completely full. If the river rises further there will be a flood.
- *Peak discharge*: the highest level that a river reaches during a flood.
- *Lag time*: the time between the maximum rainfall and the peak discharge. Drainage basins with a lot of overland flow have a short lag time.
- *Falling limb* (or *receding limb*): this is when river levels fall, after the peak discharge. It is less steep than the rising limb because throughflow is now reaching the river.
- *Stormflow*: stream discharge after a rainstorm, produced by a combination of overland flow and then throughflow. It is overland flow that makes the greatest contribution to the flood peak.
- *Baseflow (groundwater flow)*: Stream discharge produced by water seeping from the bedrock. It is a very slow process.

Influences on the shape of the storm hydrograph

The factors affecting the storm hydrograph are the same as the factors affecting river discharge. The speed at which the input of rainfall arrives in the river channel is the key influence. It is the balance of overland flow (relatively quick), throughflow (medium speed) and baseflow (relatively slow) that determines the shape and size of the storm hydrograph.

Precipitation

Three aspects of precipitation influence the shape and size of the storm hydrograph:

- Prolonged rainfall leads to saturated ground and a lot of overland flow.
- Intense rainfall usually means that the infiltration capacity is exceeded, even in a permeable basin. This produces overland flow.
- Snowfall. Snow can't flow into the river because it is frozen. Snow often melts when a depression brings more precipitation in the form of rain. The warm air and the rain melt the snow, so two lots of precipitation reach the river together. The ground under the snow is often frozen and impermeable; therefore all the rainfall and the snowmelt run over the surface, producing a rapid and massive input of water into the river.

Temperature

In summer it is warm so evaporation is high. In winter it is cold so evaporation is low and more precipitation goes into the river. Frozen ground leads to a lot of overland flow.

Vegetation

Forests encourage interception, evapotranspiration and infiltration. Forested areas have smaller flood peaks.

Seasonality

The three factors mentioned above show that similar inputs of rainfall can have different effects on the storm hydrograph at different times of the year.

Soil and rock type

Permeable soil and rock reduce overland flow and enhance throughflow and baseflow. Impermeable soil and rock enhance surface runoff.

Basin relief

Steep slopes and high relief in the drainage basin tend to get water to the river quickly and create high flood peaks.

Urbanisation

Tarmac and concrete increase overland flow, so water gets to the river faster. Gutters and drains speed up throughflow.

Comparing storm hydrographs

Different drainage basin factors produce differing storm hydrographs. We need to consider the contribution that overland flow, throughflow and baseflow make to the typical storm hydrograph.

- Rain falls on the drainage basin.
- The overland flow arrives first and builds up the flood peak.

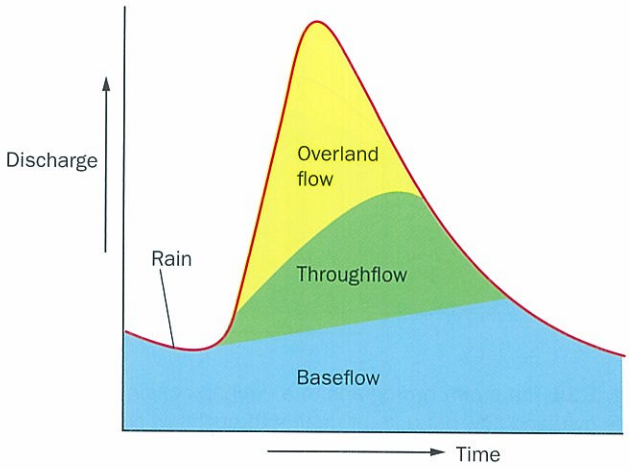

Fig. 1.13 The makeup of a typical storm hydrograph

- After several hours or days (depending on the size of the drainage basin) the overland flow reduces and eventually stops. By this point, throughflow is contributing to the river's discharge and this stops the floodwaters going down as quickly as they rose. As a result, the falling limb is not as steep as the rising limb.
- Eventually, baseflow takes over. Baseflow takes much longer to reach the river than the other two flows, but because the groundwater store is vast, it keeps on supplying water to the river well after the rainfall has stopped. This is why most rivers don't dry up during a period of dry weather.

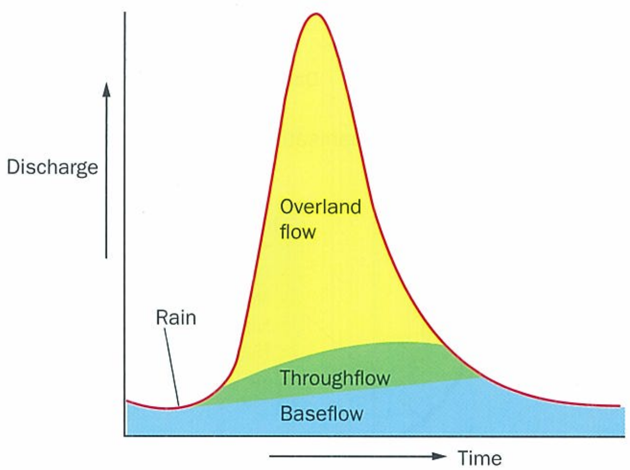

Fig. 1.14 The storm hydrograph of a drainage basin with a lot of overland flow but not much throughflow and baseflow

Fig. 1.14 is typical of a deforested drainage basin or a drainage basin with impermeable soil and bedrock. It is also typical of an urbanised drainage basin. Notice that even in an impermeable or deforested drainage basin there is always some infiltration and percolation.

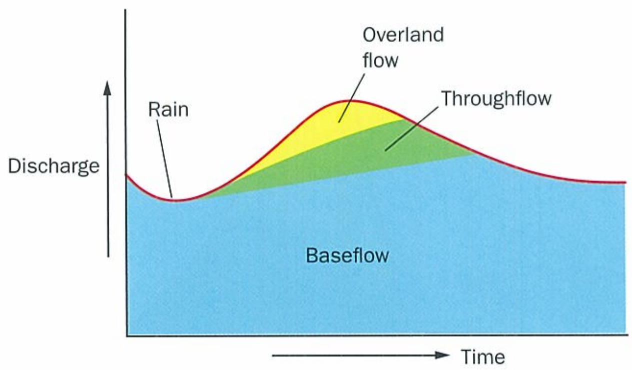

Fig. 1.15 The storm hydrograph of a drainage basin with very little overland flow but a great deal of throughflow and baseflow

Fig. 1.15 is typical of a well-forested drainage basin or a drainage basin with permeable soil and bedrock. The lag time is long and peak discharge is low. Baseflow is controlling the discharge of this river.

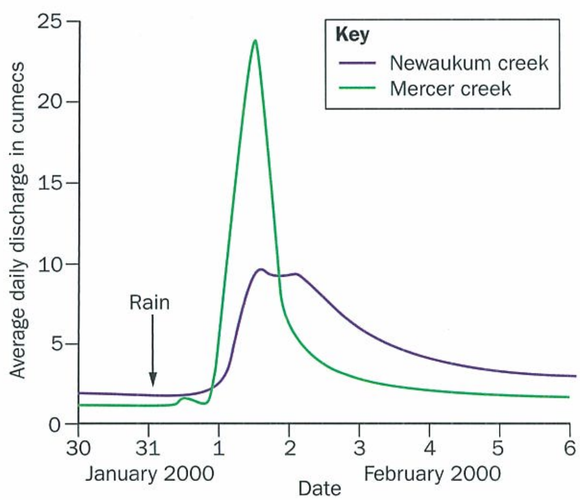

Fig. 1.16 The impact of urbanisation on the storm hydrograph

Fig. 1.16 shows the storm hydrographs for two, very similar and neighbouring drainage basins in western Washington, USA. Both drainage basins received equal inputs of rainfall from the same storm on 31 January 2000. Discharge in Mercer Creek, an urbanised drainage basin, increased more quickly and reached a higher peak than discharge in Newaukum Creek, a neighbouring rural drainage basin of equivalent size.

9. Study Fig. 1.16. Suggest reasons for the differences in the two storm hydrographs.

River channel processes and landforms

Channel processes

The **river channel** is the 'trench' in which the river flows. It is defined by the river bed and the river banks.

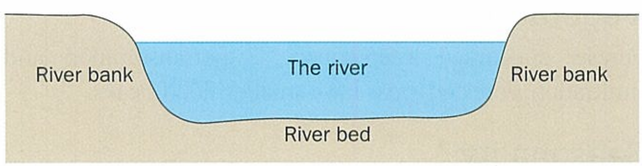

Fig. 1.17 A cross-section of a river channel

Water flows downhill through the river channel. Because the flowing water has mass and velocity, it also has energy and it uses this energy to do work, changing the shape and nature of the river channel. Considerable changes to the river channel occur as the river flows from its source to its mouth. These

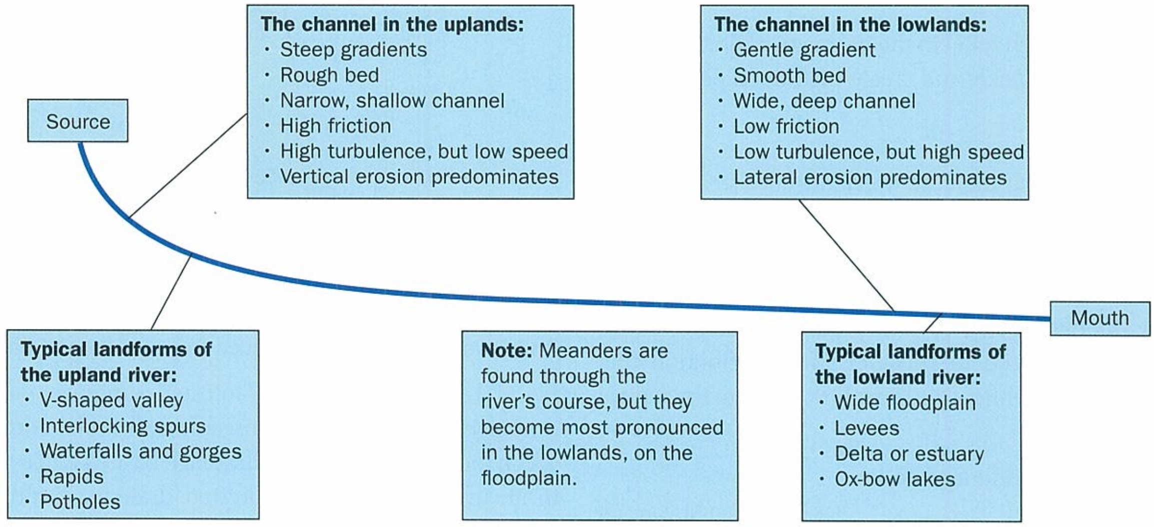

Fig. 1.18 The long profile of a river channel