1. **What is a drainage basin?** A drainage basin or river basin is an area of land drained by a river and its tributaries.

2. **What is the Hydrological Cycle and why can it be regarded as a system?** The hydrological cycle (water cycle) is the constant movement, or transfer, of water between the sea, land and atmosphere. You have done this so many times!

The part of the hydrological cycle that operates on the land is called the drainage basin system. It is a system because it is made up of inputs, flows, stores and outputs.

- **Inputs:** precipitation
- **Storage:** Interception (trees and plants)/ Surface storage (puddles and lakes)/ Soil moisture (stored in the soil)/ Groundwater (stored in the rocks underground)
- **Flows or Transfers:** surface runoff (water in streams and rivers)/ Throughflow (water moving within the soils)/ Infiltration (water soaking into the soil)/ Percolation (water moving into the rocks)/ Groundwater flow (movement of water deep within the ground)
- **Outputs:** Transpiration (water vapour released by plants and trees)/ Evaporation (water changed into water vapour by the heat of the Sun).

[http://www.nwlg.org/pages/resources/geog/hydro_cycle/hydro/cycle.htm](http://www.nwlg.org/pages/resources/geog/hydro_cycle/hydro/cycle.htm) Try this exercise!

3. **What is River Discharge?** The amount of water passing a given point of a river in a given time (measured in metres per second)

4. **Does river discharge remain constant?** No! Rivers are mainly affected by the weather - when rainfall is high rivers discharge is likely to be high. However, water is stored in the system, which can mean that it takes time for the water to reach the river. Therefore in times of dry weather water still enters the river.

5. **What are River Cross Sections (Profile) and Long Profiles?**
6. River Processes – How do Rivers Erode?

**Attrition**
Material is moved along the river bed, collides with other material and breaks into smaller pieces.

**Corrosion**
A form of chemical erosion. The banks of the river bed and banks are dissolved by acids in the water.

**Erosion**
- Erosion is the wearing away of the land.
- Most erosion occurs during flooding
- There are 4 main types of Erosion

**Corrision**
Caused by fine material rubbing against the river bank. Rather like the action of sandpaper.

**Hydraulic Action**
The force of water hitting the banks of the river. It wears them away and causes them to collapse.

7. River Processes – How do Rivers Transport Sediment?
The material transported ranges from sand particles, pebbles and even large boulders. There are 4 main ways that material can be transported:

1. **Traction**: Large rocks and boulders are rolled along the river bed.
2. **Saltation**: Smaller stones are bounced along the river bed in a leapfrogging movement.
3. **Suspension**: Fine material is light enough to be carried by the river. This discolours the water.
4. **Solution**: Some minerals can be dissolved in the water.

8. River Processes – Deposition
Deposition is the dumping of material and happens when the river loses its energy. This may be during a dry spell, on the inside of a river bend, or when the river reaches the sea (read on for more on this).

9. What Landforms are found in Upland Areas?

- **V-shaped valleys**: When rivers carry material this can cause erosion. The material cuts downwards and deepens the bed of the river (abrasion). However, the banks/sides of the valley do not remain the same. The valley sides become eroded and weathered and the soil moves downhill through gravity. This means that the valley becomes V-shaped because the erosion deepens the valley faster than it widens it.

- **Interlocking spurs**: The river winds its way around ridges of resistant rock called interlocking spurs. They are like the teeth in a zip-fastener.

- **Waterfalls**: (Remember High Force on the River Tees) These occur where a band of hard rock lies on top of a band of soft rock. The soft rock wears away more quickly than the hard rock and the hard rock is left unsupported. The hard rock then collapses and the process starts all over again. Over time as the waterfall retreats upstream a steep-sided gorge will be left behind.
10. **What Landforms are found in Lowland areas?**

**Meanders and ox-bow lakes:** as the river flows in flatter land the river develops large bends called meanders. These meanders can shift their shape and position over time. As a river goes around a river bend most of the water is pushed to the outside causing **erosion** (abrasion/hydraulic action mainly). This produces an asymmetrical cross section shown in the diagram on the right.

On the inside of the bend the flow is much slower so **deposition** occurs- this makes the channel much shallower and gently sloping. As the erosion continues the neck of the meander becomes narrower and eventually the river cuts right through the neck of the meander. Deposition then blocks the old meander bend to leave an ox-bow lake. This sequence is shown in the diagram below.

![Diagram of meanders and ox-bow lakes](image)

**TIP!** Practice sketching this diagram- often required for exams. Similarly, do the same for waterfall formation!

**Floodplains and levees:** the flat land over which the river meanders is called the floodplain. During times of flood a thin layer of material called silt is spread over the floodplain, which is good for farming. However, larger sediment (such as sand and gravels) is deposited along the banks of the river. When the river floods the sudden increase in friction causes the largest sediment to be deposited first along the banks of the river. These build up over time to form a natural embankment called a levee. Sometimes levees can be strengthened to provide flood. However, the finer sediment (called **alluvium**) is carried away from the river to create a floodplain.

![Diagram of floodplains and levees](image)
Deltas: when a river enters a lake or the sea the river slows down and material is deposited. This material builds up to form a delta. Deltas only form when a river deposits material too fast for the sea to remove it. This can be due to the river carrying large amounts of material or when the sea has weak currents. Deltas can provide very good soils for farming (e.g. Bangladesh-Ganges, Egypt-Nile) but are always at risk from flooding.

11. Identifying river features on maps

V-shaped valley  Tributary  Confluence  Meander
Levees  Floodplain  Oxbow lakes

12. Flood Hydrographs

Have a look at the hydrograph below- can you fill in the blanks with the terms below?

- Lag time: the time taken from peak rainfall to peak discharge
- Peak Discharge: the maximum flow (discharge of the river)
- Rising limb: the increase in the river flow towards peak discharge
- Falling limb: where river falls back to pre-rainfall event discharge level
- Overland flow/runoff: the water that can’t be stored or intercepted during then rainfall event
- Peak Rainfall: The point where rainfall is at its highest.
Hydrographs can have different shapes. Some have a flow that goes up very quickly to a high peak discharge and then returns to the pre-flood conditions quickly too. This is caused a ‘flashy’ response. Some reasons for responsive rivers are given below:

- **Rock type:** Hard (impermeable rock like granite) will not allow water in to it whereas a rock like chalk does. Therefore, areas with impermeable rock will have a responsive hydrograph.
- **Precipitation:** A heavy storm will result in excess water flowing into the river as the land can not absorb (infiltration) the water. A light shower will not have this effect and will not influence the flow of the river. Snow will not enter the river immediately, but could cause a problem when it melts.
- **Slope angles:** Rivers with a steep slope angle will flow faster, but it is also to do with the speed in which rainwater will enter the channel. Water will be transferred quickly when it falls on a steep slope due to gravity resulting in a more responsive river.
- **Vegetation:** Deciduous woodland will intercept rainfall and prevent it (or at least slow it) from entering the river. However, an area of grassland or heath will intercept less rain and will promote a more responsive river response.
- **Prior precipitation:** If the drainage basin has already received a high amount of water it will not be able to absorb any more - this will promote runoff into the river and produce a more responsive hydrograph.
- **Urbanisation:** The building of roads and sewers etc. prevents infiltration. Water is moved rapidly to the river where a ‘flashy’ response is produced. Humans can also influence hydrographs by regulating the flow of the river- this can be done by the use of reservoirs.

13. **Flooding** - This is where the flow of water exceeds the capacity of the river (i.e. the river is above ‘bankfull’ level). The causes of flooding can be found in the points above. Can you think why the last point is in a different colour? The reason for this is that the reasons have been categorized into PHYSICAL and HUMAN causes.

There are other ‘human’ reasons for flooding though:

- Dam burst (not common fortunately!)
- **Deforestation:** The removal of trees reduces interception and evapotranspiration resulting in increased runoff and soil erosion. The eroded material finds its way into the river and aggrades (build it up) the river bed, which promotes further flooding. (see diagram on the right.)
- **Building in inappropriate areas- i.e. floodplains**

14. **Case Studies of flooding**

A. **Mississippi Floods, 1993- an MEDC flood on a large scale**

**What?** An example of river flooding and possible mis-management. The Mississippi flooded in 1993 with disastrous consequences.

**Where?** The Mississippi drainage basin covers 1/3 of the USA. The river flows north-south in the central parts of the USA. The river is 3800km in length and flows through 10 states.

**Effects?**

- Deaths = 43
- Cost = £8billion
- Threat of disease
- Evacuated = 50,000
- River traffic halted for several months
- Land flooded = 26,000km²
Why? Heavy rain in April 1993 saturated the soil and a series of thunderstorms produced flash floods. The levees surrounding the towns were put under serious pressure and collapsed helping cause an area larger than the British Isles to be flooded. Many felt that humans interfering with the channel had made the situation worse.

How has the threat of flooding been reduced? People had always used levees to protect themselves from flooding, but a large flood in 1927 made them realise that they needed to something different:

- Dams and reservoirs on the Missouri River - 6 huge dams, which apart from preventing flooding, also provides water supply and electricity.
- Afforestation - trees have been planted to delay the water from entering the channel.
- Strengthening levees - 25x8 metres concrete mattresses have been placed to strengthen/heighten the levees.
- Straightening the river - to get the water away as quickly as possible (cut the meanders).
- Diversion spillways - overflow channels, which can take surplus water during times of flood.
- TVA (Tennessee Valley Authority) controls the river levels of the Tennessee River through a series of dams and reservoirs

B. **Boscastle - an MEDC flood on a small scale**

What? A flood in the UK (1 in 400 year event)

When? 16/8/2004

Why? 8" of rainfall in just a few hours resulted in huge amounts of water reaching Boscastle from Bodmin Moor. The water was produced by a huge thunderstorm which stayed over the Boscastle area. High tide prevented the water from entering the sea. Steep slopes and steep gradient of the river (it fell 1000 feet in just 3.5 miles) gave the River Valency huge amounts of power.

Effects?
- 440 million gallons of water (like the River Thames flowing through the tiny village of Boscastle).
- 100 rescued.
- Roads and bridges destroyed
- 115 cars swept away
- Problems for the tourist industry
- Estimated £50 million worth of damage
- NO DEATHS!

C. **Bangladesh floods, 2004. An example of flooding in an LEDC**

Where? Bangladesh in Asia

What? A huge flood that caused a huge amount of damage in a country that is not fully prepared due to a lack of funds.
**Effects?** The flood event lasted a month and in which time resulted in the deaths of over 600 people. 7 million were left homeless, 2.6 million homes badly damaged, 11,000 schools damaged, 3,000 bridges destroyed, 30,000km of roads destroyed or badly damaged, 2 million hectares of crops lost. $4 BILLION DAMAGE!

**Why?** Bangladesh is low and flat- in fact, most of it is a delta where the Ganges and Brahmaputra rivers deposit vast amounts of silt before they enter the Indian Ocean. Monsoon rains fall over the Himalayas (the source of these great rivers) bringing a massive volume of water into Bangladesh. This hasn't been helped by people in India and Nepal cutting down trees in the Himalayas, which has resulted in more water reaching the rivers. The soil on these slopes has also entered the river reducing the capacity and promoting further flooding. The population of Bangladesh is rising rapidly and more and more unsuitable (flood prone) land has been used for settlements.

**What was their response?** This is difficult for Bangladesh. They would really like to spend huge amounts of money on building embankments and dams, but they do not have the money to do so. The diagram shows what they would like to do, but in 2004 they were only able to provide a limited response and relied heavily on foreign aid.

**Short term**
- Boats to rescue people
- Emergency supplies for food, water, tents and medicines
- Food for livestock
- Repair and rebuild houses, as well as services such as sewage etc
- Aid from other countries

**Long term**
- Stop chopping down trees (deforestation) in Nepal & Himalayas
- Build 7 large dams in Bangladesh to store excess water
- Build 5000 flood shelters
- Develop an effective Flood Warning Scheme

**D. Three Gorges Dam – River Management on a huge scale**

**What?** Example of river management and renewable energy (use this case study for Resources and Tourism topic too)

**Where?** The Yangtze River, China

**Why is it being built?** To improve navigation for ships and to prevent the flooding of people (300,000 people have drowned in the last 70 years) and good farmland.

**What is the 3 Gorges Dam?**
- Biggest dam in the world
- Biggest HEP station in the world
- Just under 2 km long
- Dam height 185 metres
- 600 km reservoir to build up behind the dam
- $20 billion to build
15. How do you cope with floods?

You can expect a question on this in your GCSE exam. Often the management strategies involve trying to lengthen the amount of time it takes for water to reach the river channel, thereby increasing the lag time. Flood management techniques can be divided into hard and soft engineering options.

- 'Hard' options tend to be more expensive and have a greater impact on the river and the surrounding landscape (dams, artificial levees, flood channels + river diversion etc.)

- 'Soft' options are more ecologically sensitive (flood plain zoning, planting trees, flood insurance etc)

Over the years, the approach has been to build structures to prevent flooding, but things have changed over the years. The belief is that we should now work with nature rather than against it as this is the more sustainable approach- this is particularly important for LEDCs as the can't afford the large-scale 'hard' strategies (e.g. dams) that MEDCs can. Some strategies are analysed below:

<table>
<thead>
<tr>
<th>Approach:</th>
<th>Aim:</th>
<th>Advantages:</th>
<th>Disadvantages:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regulate land use/flood plain zoning</td>
<td>Promote wise use of land, to reduce flooding and limit building</td>
<td>Cheap, immediate effect and long term, provide for most suitable use of land</td>
<td>Does not prevent floods, not always applied well or to existing land uses</td>
</tr>
<tr>
<td>Dams and reservoirs</td>
<td>Protect existing land uses, limit flooding, promote recreation</td>
<td>Protects existing land uses, controls water flow, allows recreation</td>
<td>Costly, Lengthy construction, maintenance needed, wildlife destroyed, communities disrupted, sedimentation.</td>
</tr>
<tr>
<td>Acquire flood plain land for public use</td>
<td>Reduce losses from floods</td>
<td>Permanent, numerous benefits</td>
<td>Costly, sites not always suitable for other uses, land shortage may result</td>
</tr>
<tr>
<td>Insure against floods</td>
<td>Promote flood regulations</td>
<td>Spreads cost of flood losses</td>
<td>Can be costly</td>
</tr>
<tr>
<td>Install warning systems</td>
<td>Warn property owners of threats, allow for evacuation</td>
<td>Allows people to adjust to the flood threat</td>
<td>Requires education, systems must be carefully maintained</td>
</tr>
</tbody>
</table>
### How Does the River Tees Change Downstream?

**CASE STUDY E:** The River Tees is 100km in length yet undergoes a dramatic change along its course- “the maximum variety in the minimum distance”. Examiners often ask about how a river changes from source to mouth- the River Tees is your example.

<table>
<thead>
<tr>
<th>Where?</th>
<th>What is the Physical Geography? Altitude/climate etc)</th>
<th>Types of River Landforms (use named examples)?</th>
<th>Sediment and changes in channel (include sketch &amp; an explanation of why it is like it is)</th>
<th>Land use and human modifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>UPPER COURSE</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>✓ Moor land on the Pennines 600 metres high</td>
<td>✓ V-shaped valleys predominate near the source, with strong vertical erosion due to corrosion/abrasion.</td>
<td>Source</td>
<td>✓ Reservoir for drinking water and to control discharge</td>
<td></td>
</tr>
<tr>
<td>✓ Very wet-1200mm per year minimum</td>
<td>✓ Interlocking spurs found near the source</td>
<td>✓ Very angular</td>
<td>✓ Land use dominated by farming (pastoral)</td>
<td></td>
</tr>
<tr>
<td>✓ Weather very changeable</td>
<td>✓ As the river drops to about 350 metres the river starts to meander and despite the presence of V-shaped valleys with steep sides, small floodplains start to form.</td>
<td>✓ Large as the river doesn’t have the power to move them</td>
<td>✓ Very little near the source which is very remote</td>
<td></td>
</tr>
<tr>
<td>✓ Moorland acts as a sponge- water that can't be absorbed eventually runs off into the streams that form</td>
<td>✓ The River flows over the famous 21 metre high High Force, which has developed due to the presence of hard and soft rocks. The volcanic Whin Sill provides the cap rock, with sandstone, coal and limestones underneath.</td>
<td>✓ All sorts of sizes, but mostly large</td>
<td>✓ Romans used the Whin Sill to build Hadrian’s wall on- same rock as High Force</td>
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<tr>
<td></td>
<td>✓ The headward erosion of the waterfall has resulted in the formation of a steep-sided gorge.</td>
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<tr>
<td>MIDDLE AND LOWER COURSES</td>
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</tr>
<tr>
<td>✓ River more powerful as it leaves its upper course</td>
<td>✓ Floodplain develop to a large size- 10km wide in places</td>
<td>Sediment in Middle</td>
<td>✓ 95% farmland</td>
<td></td>
</tr>
<tr>
<td>✓ Land is flatter</td>
<td>✓ River starts to Meander on a much larger scale</td>
<td>✓ Much smaller-small stones are transported further</td>
<td>✓ Pastoral still there, but increase in the proportion of arable land (e.g. Oil seed rape)</td>
<td></td>
</tr>
<tr>
<td>✓ Floodplain wider</td>
<td>✓ Levees flank the channel in places</td>
<td>✓ Sharp edges almost completely removed due to combined processes of abrasion and attrition</td>
<td>✓ Near the mouth, steel, chemical, and other heavy industry can be found</td>
<td></td>
</tr>
<tr>
<td>✓ Nearing base level at the lower section and the mouth</td>
<td>✓ Really large loops form</td>
<td></td>
<td>✓ Used for transport</td>
<td></td>
</tr>
<tr>
<td>15°C in March when the film was shot, yet at the same time was snowing at the source</td>
<td>✓ Ox-bow lakes</td>
<td></td>
<td>✓ Bridge at Stockton ruined the town of Yarn as boats could no longer reach the town</td>
<td></td>
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<tr>
<td></td>
<td>✓ Near the mouth the river has a tidal estuary and used to have marshland there too.</td>
<td></td>
<td>✓ Victorians decided to chop off meander loops with new 3km artificial section</td>
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<tr>
<td></td>
<td></td>
<td>Sediment at Mouth</td>
<td>✓ Marsh areas drained</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>✓ Very fine silts and clays as these get transported furthest, but also due to erosion.</td>
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<td></td>
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<tr>
<td></td>
<td></td>
<td>✓ River loses its energy and deposits the sediment</td>
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<tr>
<td></td>
<td></td>
<td>✓ Helped by the proves of flocculation at the mouth where salt water comes into contact with the fresh water</td>
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</tr>
</tbody>
</table>