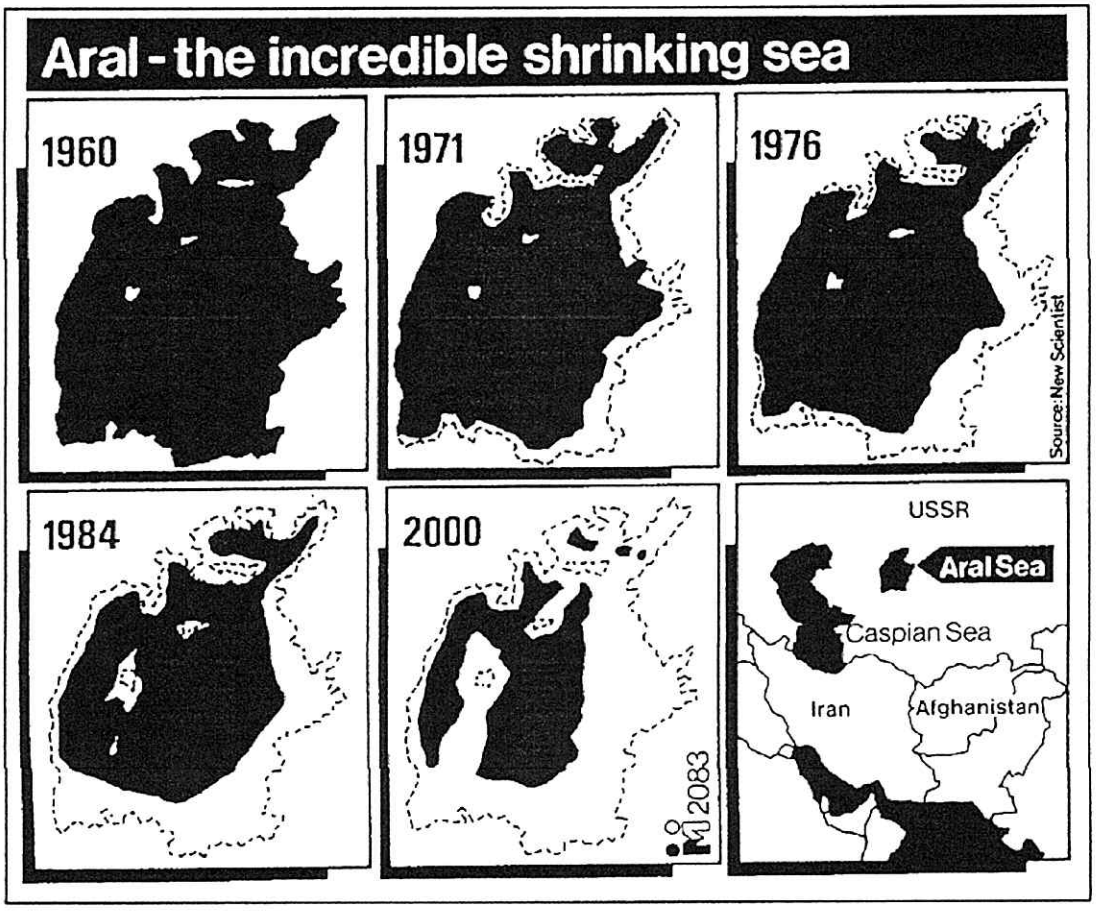


The Aral Sea was one of the world's largest inland seas (4th largest in 1960) and been in existence for 35 million years; it has been transformed in four decades into the scene of one of the world's worst ecological disasters. Around 50,000 square kilometres of the lake's surface had dried up by 2004 - this is an area larger than twice that of Wales. By 2015 it had shrunk substantially more.

What has caused the Aral Sea to shrink?

The Soviet Union government's desire to produce cotton at any price since the 1970's is the main reason for the disaster. The cotton growing region consumes enormous quantities of water and irrigation schemes were constructed on the Syrdar'ya and Amudar'ya rivers to feed the cotton crop.

About 50% of the Amudar'ya's flow is used for irrigation but because of high evaporation rates much of the irrigation is ineffective. The Soviet Union decided to develop its cotton industry because it didn't have an extensive synthetic fibre industry.

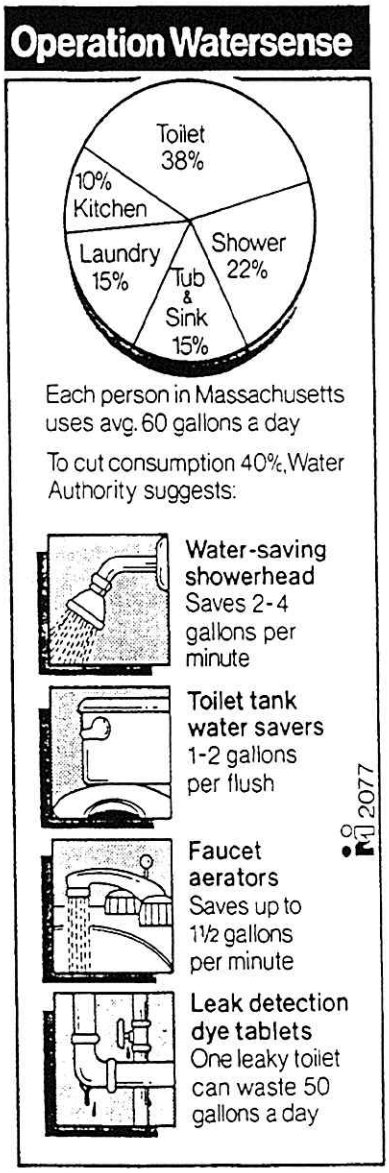
Consequences of the Aral Sea scheme

- Evaporation of irrigation water causes salts to be uplifted in the soil.
- Evaporation of the Aral Sea has left the old seabed encrusted in salt.
- Pesticides which were banned in the West were used in enormous quantities - around 52 kilograms per hectare - much of the chemicals end up as a dust residue on the fields.
- Salt and chemical residues were carried in the wind and these 'salt storms' damaged crops and affected livestock and human health.
- Infant mortality was four times the national average in 1990 and thousands suffered from cancers and other serious diseases.
- The fishing port of Muynak which used to land more than 10% of the Soviet Union's total catch is now largely deserted and 30 miles from the sea's shore, other ports are even further from sea.
- The regional climate has changed because the Aral sea's moderating in fluence on temperatures has been reduced and rainfall is lower, as less water is available to be drawn up into the atmosphere.

Since the collapse of the USSR, Kazakhstan, one of the countries most impacted by this environmental tragedy has built a dam separating the North and South Aral Sea, which was finished in 2005. This has had the impact of increasing the water levels and fish stocks in the Northern Aral Sea. The Southern Aral Sea is reduced to a western ribbon of salty water in drought years.

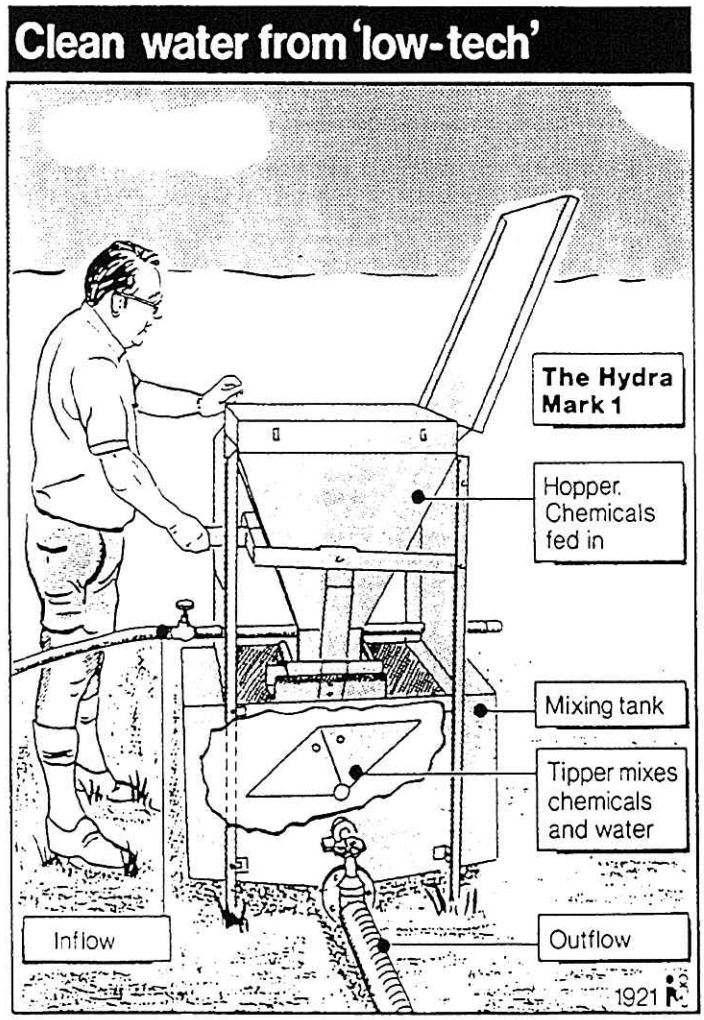
Increased domestic water consumption in developed countries has placed a strain on some water authorities. Periods of water shortage are often accompanied by advice to reduce consumption. Some water saving suggestions are listed in **Diagram 1**.

Diagram 1



Clean water in developing countries is essential to fight the war against disease. Solutions to have any chance of success have to use low technology which can be produced and maintained in rural areas.

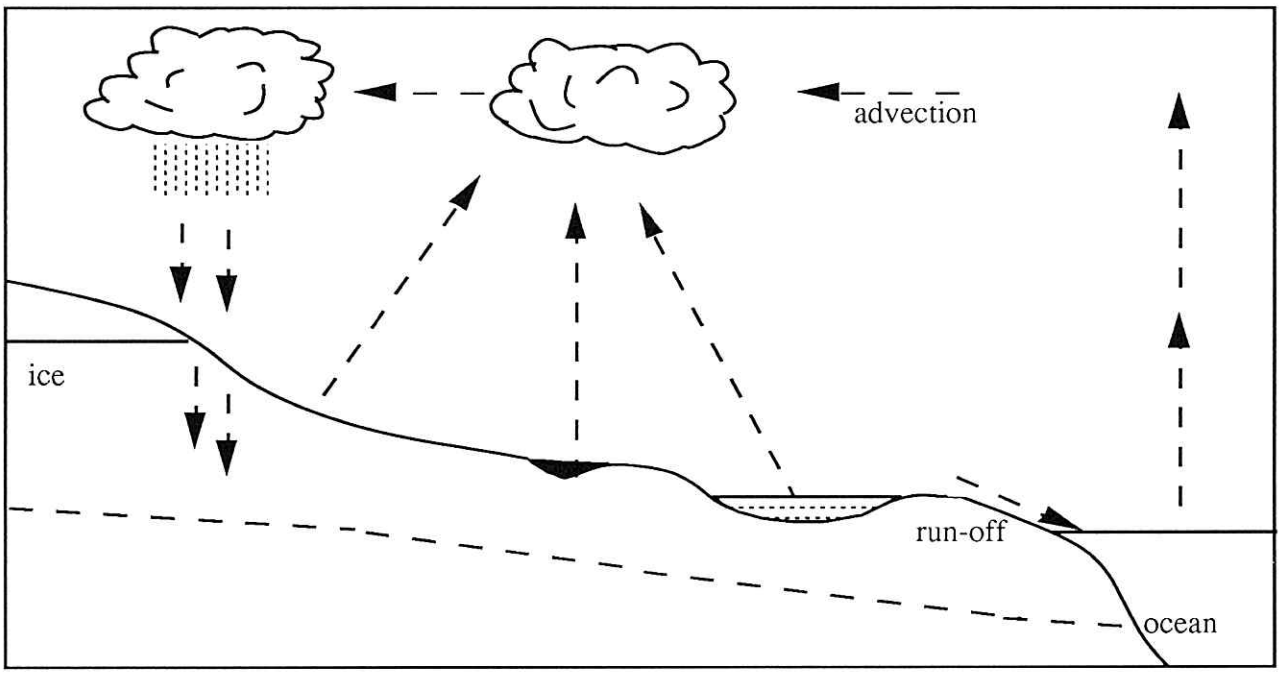
Diagram 2



Research Questions

1.. Find out about water supply problems in developed and developing countries.

2.. Water resources are becoming a source of international tension. Find out about examples of this type of disagreement and explain the background to the conflict of interest.



Q

1.. Copy then complete the **Hydrological cycle** diagram above, using the following list :

precipitation, condensation, transpiration, groundwater storage, water table, rivers and lakes, evaporation, infiltration
(labels may be used more than once)

2.. Add the following to your diagram :
- some vegetation (eg bushes and trees) and soil
- a cloud, missing from the diagram
- water storage percentages ; 2% in ice; 97% in the oceans; 1% in groundwater and 0.001% in the atmosphere.

3.. Describe the **hydrological cycle** in your own words.

4.. How are the amounts that are evaporated from the oceans and land masses balanced by precipitation and run-off?

5.. Explain the process of **transpiration** in plants.

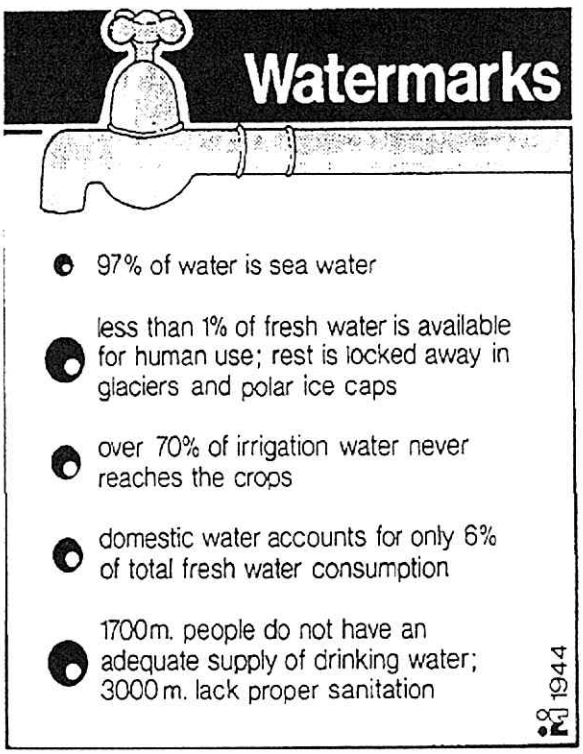
6.. Define **evapotranspiration** explaining the difference between potential and actual evapotranspiration.

7.. In what ways does the **water budget** of a hot desert area differ from that of a tropical grassland area?

Water facts

HYDROSPHERE

Water is essential for all life on earth and despite the fact that only about 3% of all water on earth is freshwater there is plenty for all current human needs. However water resources are not evenly distributed.



Daily use of water per capita

USA	3794 litres
UK	348 litres
Germany	855 litres
Denmark	318 litres
Angola	100 litres
Benin	50 litres

Cost of production of water per cubic metre

USA	$0.51
Germany	$1.91
Denmark	$1.64

Water consumption in % per sector

	Agriculture	*Household*	*Industry*
Africa	85%	10%	5%
Asia	81%	7%	11%
Europe	35%	16%	48%

The UN considers 50 litres per capita per day to be the amount of water required for preparing meals, and personal hygene. Many Africans get by with 20 litres; compared with 121 litres for personal use in Germany (split roughly equally between toilet flushing, personal hygene and other household tasks i.e. laundry, dishwashing, cooking and drinking.

Use the figures above to help you answer the following questions.

Q

1.. If domestic water use only accounts for 6% of total freshwater consumption what are likely to be the other main uses of freshwater?

2.. Why is average domestic usage of water so much greater in the developed countries than in developing countries?

3.. List some ways that could be used to reduce domestic usage in developed countries. (see sheet 21)

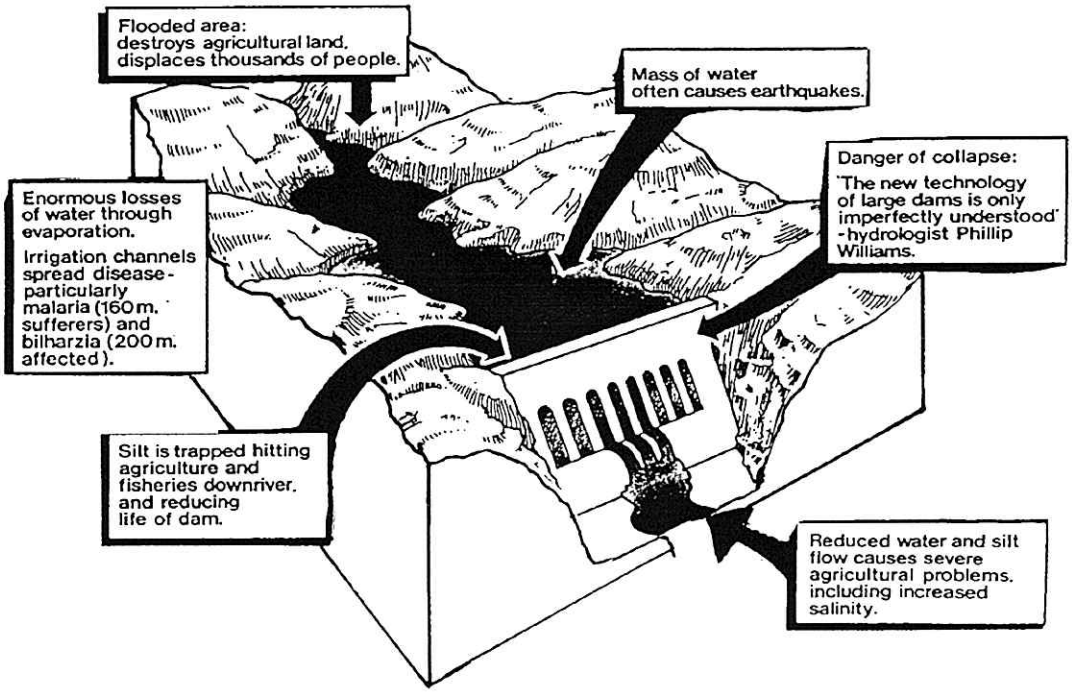
4.. Why is the cost of providing water so much less in developed countries?

5.. Suggest an explanation for the fact that up to 70% of irrigation water never reaches the crops.

6.. List the ways the **hydrological cycle** is interfered with to provide water supplies.

7.. Write an essay on the uneven distribution of global water resources.

The big dam disaster



THE PRO'S AND CON'S OF LARGE DAMS IN DEVELOPING COUNTRIES

PRO'S

1. Assists in flood prevention.
2. Provides a reliable source of water which can continue through even long droughts.
3. Provides water for growing cities and industries.
4. Provides water for irrigation which can increase agricultural productivity.
5. Can be a source of income e.g. Turkey selling water to Israel
6. Water can be used to produce electricity.

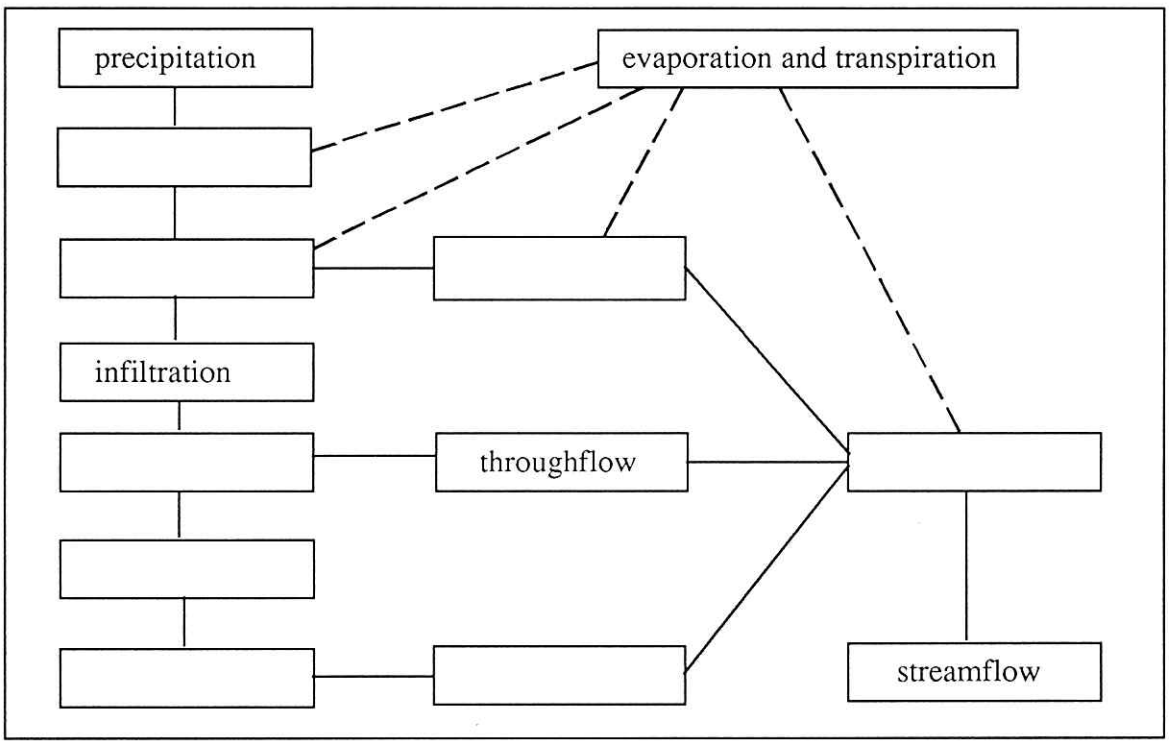
CON'S

1. Displaces rural population e.g. 70,000 people moved from their homes by the building of one dam in the Narmada valley of India (see below).
2. Stagnant water and irrigation channels provide an ideal environment for water bourne diseases such as Bilharzia and river blindness.
3. Often the best, most productive, agricultural land is flooded.
4. Disrupts communications by flooding roads between villages.
5. Financing the building of large dams can saddle developing countries with crippling international debt.
6. Dams may also cause ecological damage by flooding land which contains rare plants and animals.
7. Silt which builds up behind the dam is no longer spread by flooding rivers hence this fertile material is lost to the farmers.

The Narmada valley development project in India will eventually build 30 major dams on the Narmada river and its tributaries. The 129 metre high Sardar Sarovar dam under construction in the state of Gujarat will contain 5.8 billion cubic metres of water in a 214 kilometre long reservoir. The dam should generate 1250 megawats of electricity when it is finished in 1993 and will flood 243 villages in three states.

Q

1.. Copy then complete the drainage basin systems diagram below using the following list of terms : **interception; channel storage; soil water storage; surface storage; groundwater flow; percolation; overland flow; groundwater storage;**



Colour code the boxes using the following key

INPUT - Green
STORAGE - Brown
TRANSFERS - Blue
OUTPUTS - Red

Indicate direction of **transfers** with arrows.

2.. Write a definition for each of the important terms in the box below :

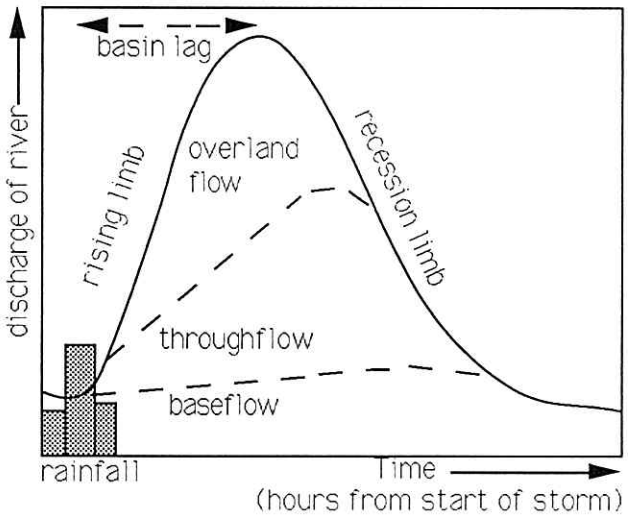
drainage basin, watershed, evapotranspiration, potential evapotranspiration, interception, overland flow, infiltration, infiltration capacity, throughflow, capillary fringe, percolation, groundwater, water table, baseflow, stream flow.

3.. Describe the passage of water in the basin hydrological cycle.

4.. Explain the relationship of **percolation rates** to **soil permeability**.

5.. Draw a diagram to illustrate the main **soil-water** and **groundwater** belts.

Storm hydrographs



A **hydrograph** is a record of **river discharge** over a period of time. Discharge is the amount of water flowing through a cross section of a river. A rivers discharge at a particular point in its course is calculated by multiplying its cross sectional area by the rivers mean (average) velocity.
River discharge in humid regions tends to increase downstream. The river with the greatest average discharge at its mouth is the Amazon, at around 181,000 cubic metres per second. This discharge is greater than the combined discharge of the next five largest rivers.

The **storm hydrograph** above shows the change in discharge caused by a period of rainfall. The river discharge rises to a peak (**rising limb**) and then falls to near its original level (**recession limb**). The recession limb is usually less steep than the rising limb because throughflow continues to feed the channel for some time after the storm has passed. The starting and finishinglevel is produced by **groundwater** seeping in from the water table and is called **baseflow**. The **overland flow** and **throughflow** which produce the peak of the hydrograph make up the **storm flow**. The recession limb of the hydrograph is largely determined by the characteristics of the river basin and is therefore much more predictable than the rising limb. The recession limb is a record of the water draining out of the river through the soil and over the surface.
The time delay between the peak rainfall and peak river discharge is called **basin lag**. This lag time depends on the characteristics of the drainage basin e.g. soil cover, rock type, vegetation cover, slope of land, drainage density, storage capacity, size of basin.

Annual hydrographs can be constructed for rivers that are continuously monitored. In the UK most rivers have their lowest discharges in late summer, when rainfall is low and groundwater flow is at its lowest.

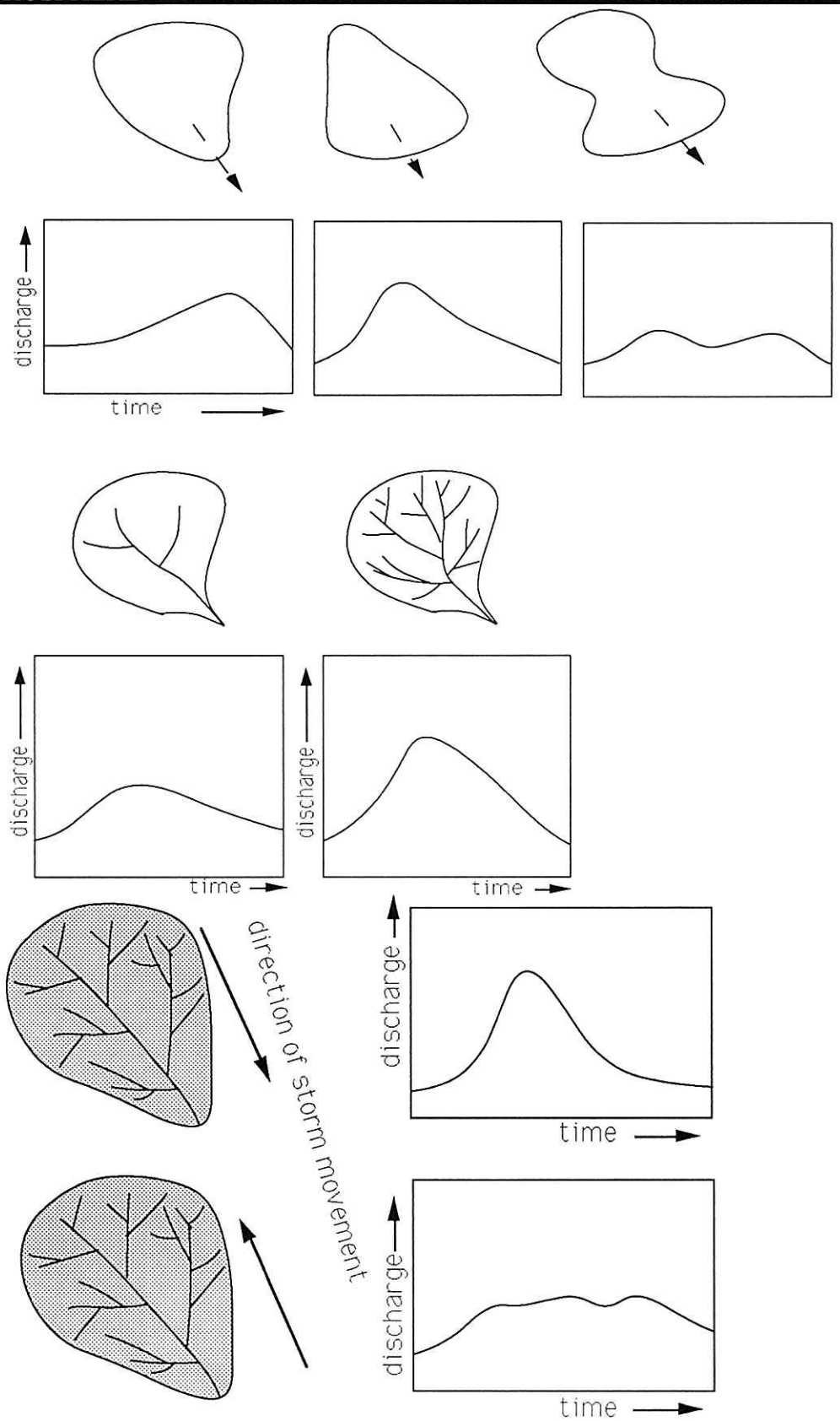
Hydrologists take river data which has been collected over a long period of time (often over 100 years) to calculate other statistics which can assist them in their work, particularly flood prevention. **Recurrence intervals** are one such useful set of statistics. The recurrence interval for a particular level of discharge is the period between such discharges.
The formula for the recurrence interval is :

$$\text{Recurrence interval in years (for a particular discharge)} = \frac{(n+1)}{R}$$

where n = number of years for which records exist
R = rank of the discharge level in the total record

Recurrence intervals are normally plotted on a graph and extrapolated to determine the probability of very large floods for which no records exists.

Storm hydrograph shape



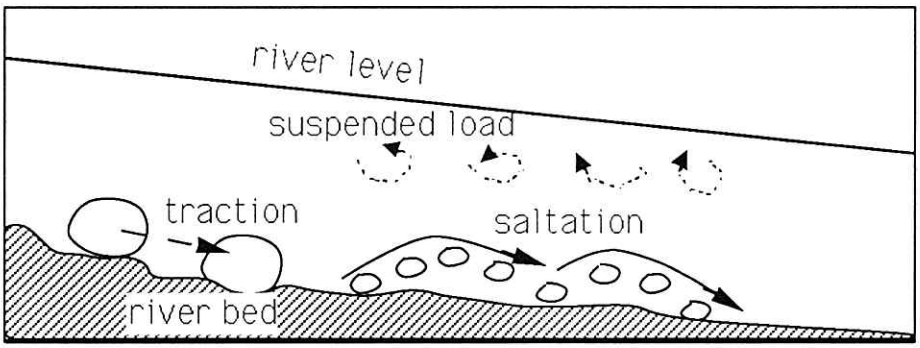
Q

Using the diagrams on this sheet describe the relationship of hydrographs to basin characteristics and storm direction.

Erosion, transportation and deposition

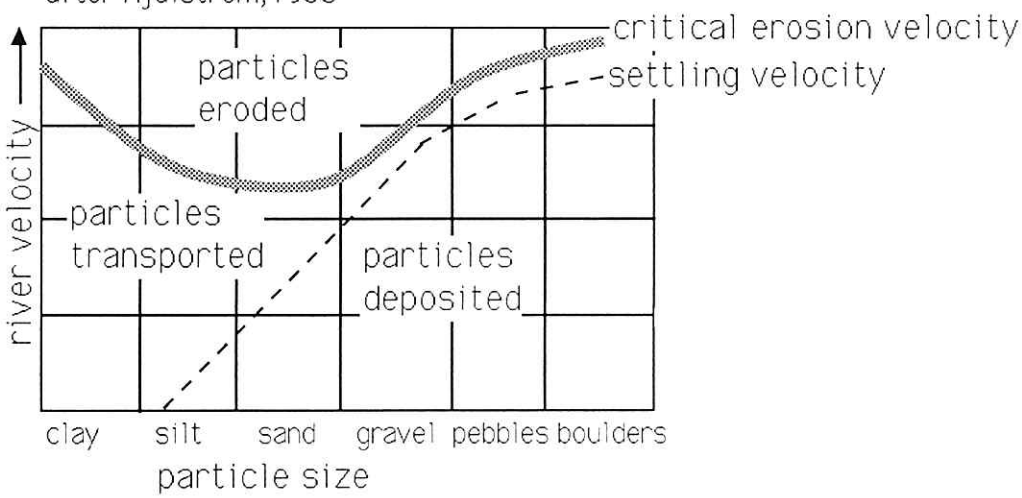
HYDROSPHERE

SEDIMENT TRANSPORTATION



RELATIONSHIP BETWEEN VELOCITY AND PARTICLE SIZE

after Hjulström, 1935



Q

1.. Describe the main types of sediment transportation as illustrated in the sediment transportation diagram above.

2.. What type of sediment transportation is not shown on the diagram?

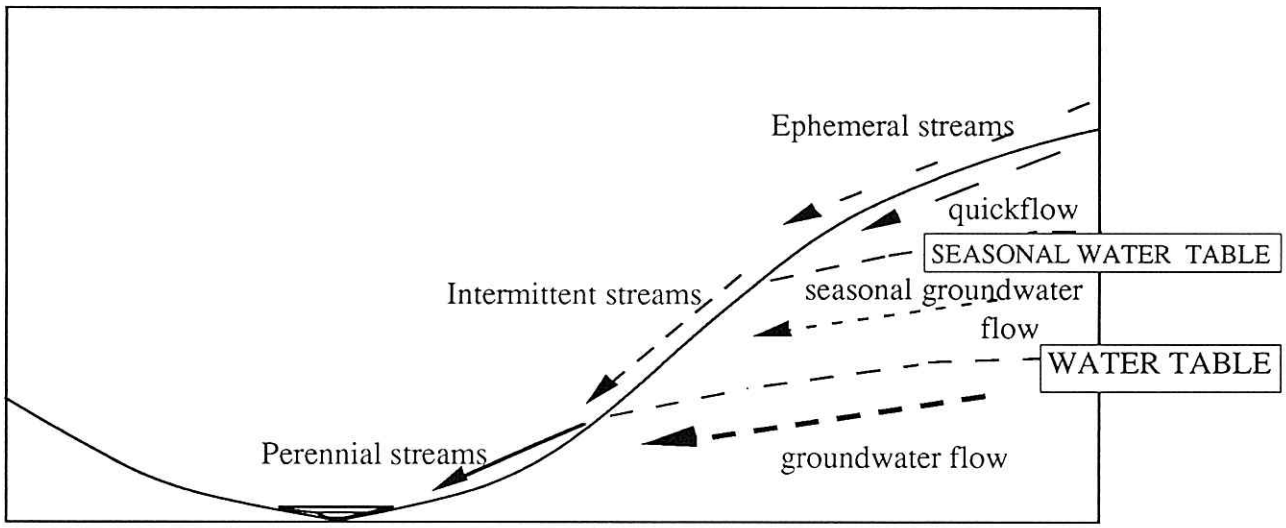
3.. What is the critical erosion velocity and why is it often shown as a band rather than a line on a graph.

4.. Briefly describe the relationship between velocity and erosion, transportation and deposition as shown on the graphs.

5.. Explain why clay and fine silt particles require greater velocities to erode them than does sand.

6.. What does the graph suggest about the pattern of erosion, transportation and deposition during a flood event?

STREAM TYPES IN HUMID REGIONS



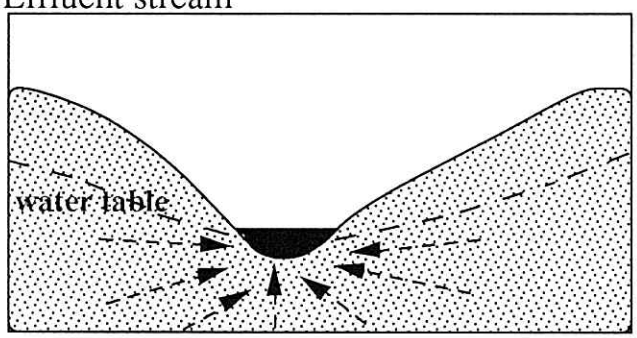
Precipitation which reaches the stream or river channel fairly rapidly as **overland flow** or **soil throughflow**, is called **quickflow**. Quickfow because it follows precipitation so closely can be a major contributer to floods. **Ephemeral streams** which are usually found at high altitudes or over very **permeable** rocks only flow when they are fed by quickflow, immediately after precipitation has occurred.

Intermittent streams are fed by quickflow and **groundwater flow**, but the groundwater flow is seasonal. In wetter conditions the water table rises and feeds the intermittent stream with groundwater flow. Whilst in drier weather the water table falls and the intermittent streams are starved of groundwater flow.

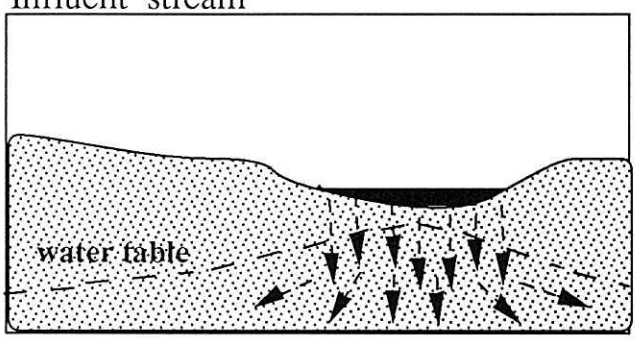
Perennial streams on the other hand are fed fairly constantly by groundwater flow as the water table is not seasonal at this level.

This hierarchy of streams can be found in many drainage basins, moving from ephemeral rills and streams near the watershed to the main 'trunk' channel.

Effluent stream

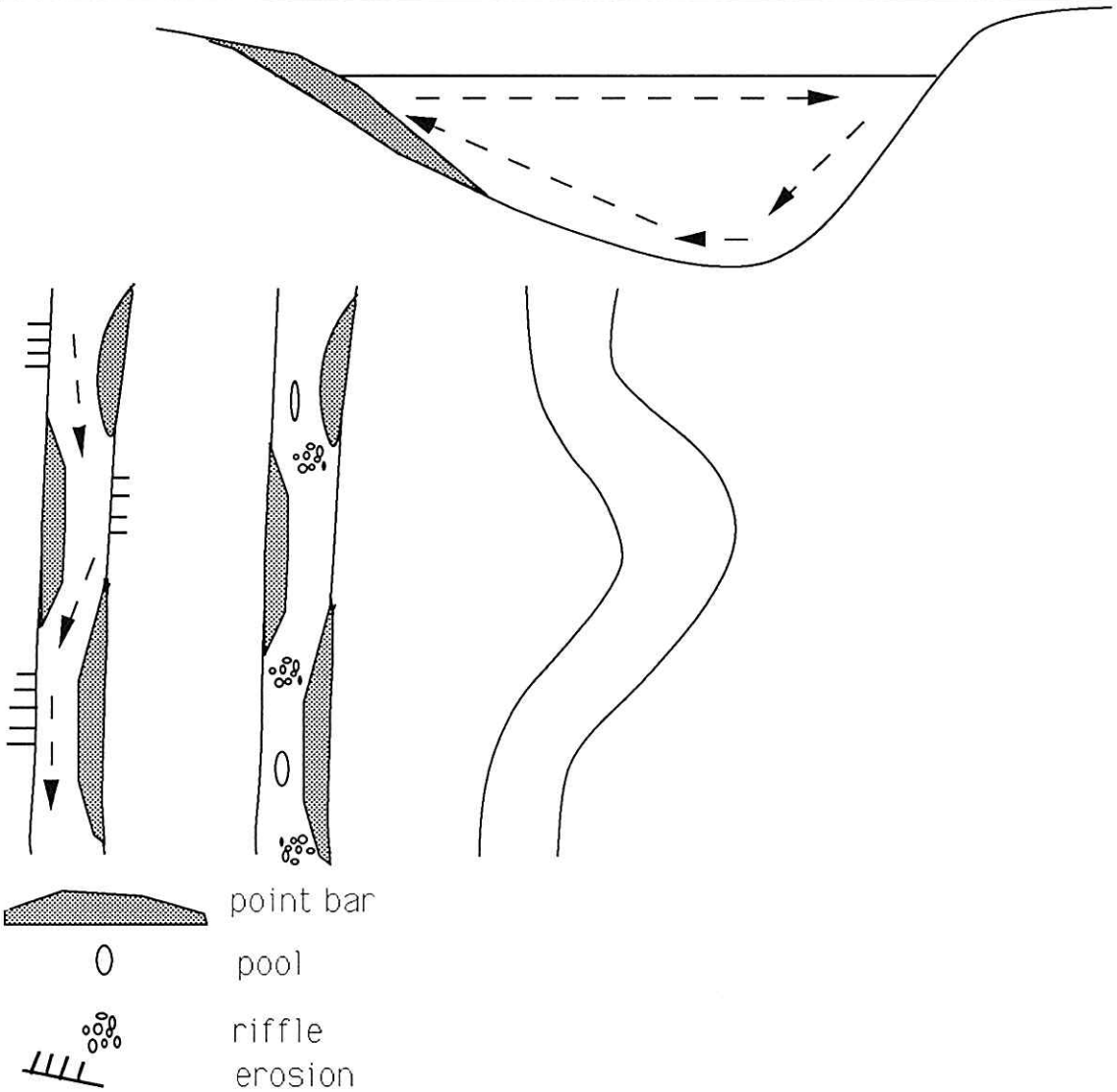


Influent stream



Effluent streams are found in humid regions and are fed by groundwater from the water table.

Influent streams are found in arid regions and water is lost from their channels by seepage downward to the water table.



Q

1.. Complete diagram 1 above by marking on the following labels :
Slip-off slope; point bar deposits ; undercutting of river bluff ; transfer of sediment from river bluff to point bar

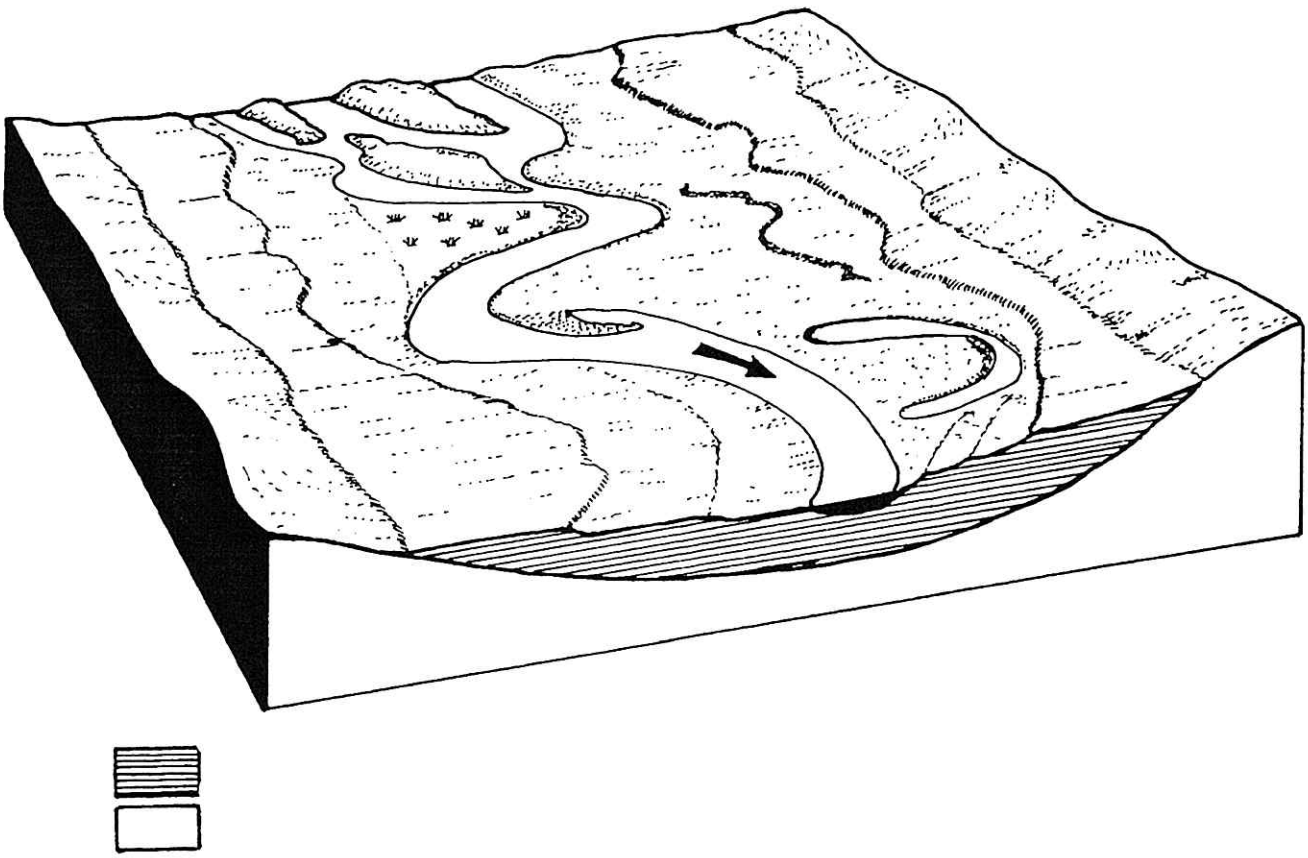
2.. Complete diagram 2 to illustrate stages in the development of meanders.

3.. Draw a diagram to show the radius of curvature of a meander and the line of fastest flow in meanders.

4.. How is sinuosity measured? Measure the sinuosity of two rivers from different parts of the UK using O.S. maps. Explain any similarities or differences.

5.. Draw a profile diagram to show riffles and pools on a stream bed.

River floodplains



Q

1.. Using the list below, label the above diagram of a river floodplain.

ox-bow lake	**meander scrolls**	**meander**	**point bar**	**marsh**
river terrace	**braiding**	**alluvium**	**bed rock**	**eyots**

2.. What evidence on the diagram indicates that the river has changed course?

3.. List the possible reasons why streams braid.

4.. Describe how river terraces are formed.

5.. Explain the formation of river floodplains.

6.. Using diagrams explain the formation of levees.

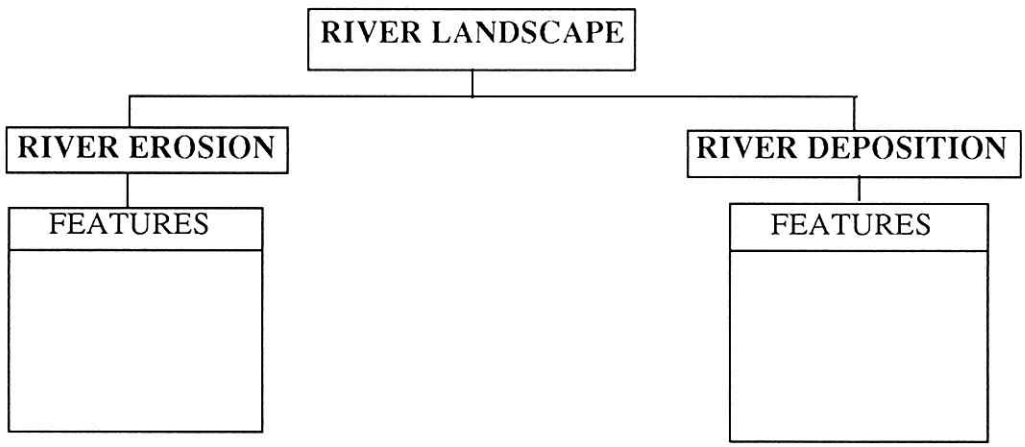
7.. What is the relationship between meander length and channel width?

Q

1.. Write a full description for each of the terms or phrases listed in the box below.

water budget	**meander**	**interception**	**waterfall**	**permeable**
rainsplash	**aquifer**	**rapids**	**aeration zone**	**quickflow**
groundwater flow	**riffle**	**basin lag**	**hydrograph**	**corrasion**
hydraulic action	**headward erosion**	**saltation**	**floodplain**	**delta**
overbank deposits	**levee**	**point bar**	**cut-off**	**arcuate delta**

2.. Copy and then complete a larger version of the table below as a classification of river features in the landscape.



3.. Choose two features of **river erosion** and two features of **river deposition**. With the aid of suitable diagram(s) explain how each of these features was formed.

4.. Which factors influence a) rate of river erosion
b) rate of river deposition
c) particle size transported?

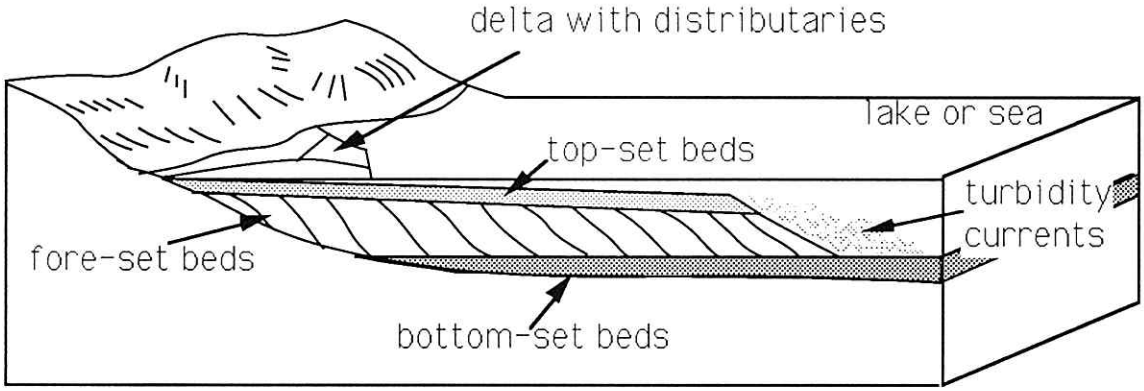
5.. Outline the main differences between the upper and lower stages of a river. You may refer to a named example of your choice.

6.. Many rivers in northern Britain exhibit features of **river rejuvination**.

a) Why has this process taken place?
b) List the main features of river rejuvination.

Deltas and levees

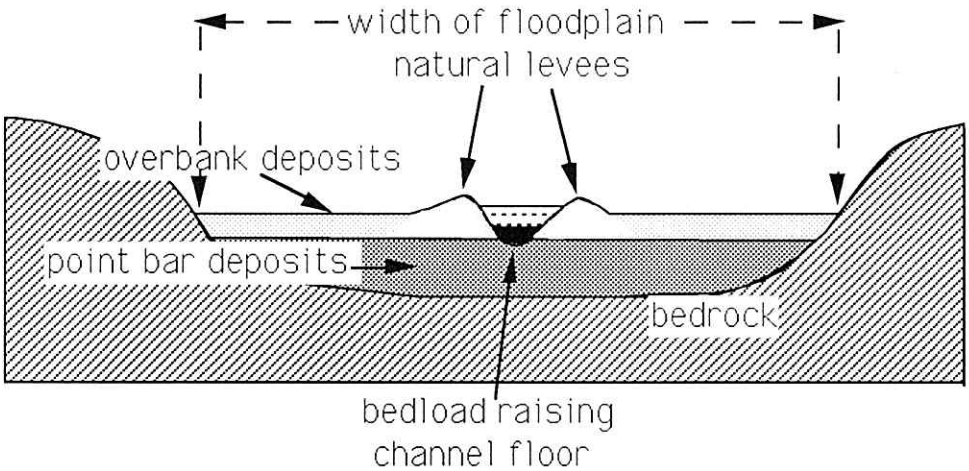
THE STRUCTURE OF A SIMPLE DELTA



Q

1.. Describe the structure of a delta.
2.. Describe the three main delta forms; arcuate, bird's foot and cuspate.
3.. What are turbidity currents?
4.. Suggest reasons why many deltas, such as the Nile Delta, are shrinking.

RIVER FLOODPLAIN AND LEVEES

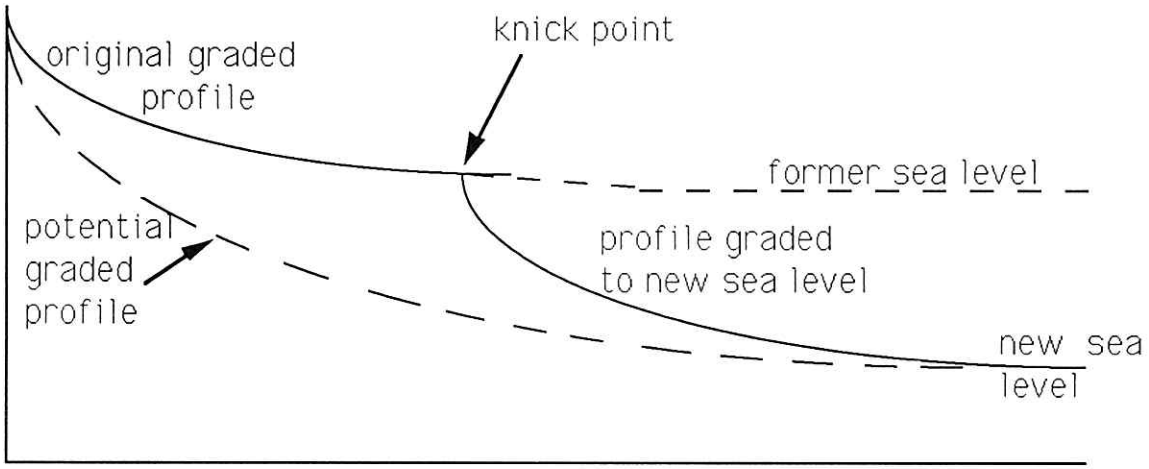


Q

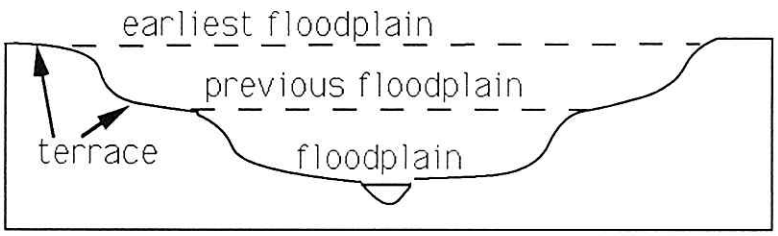
1.. Why are levees often the safest places on a floodplain during floods?
2.. Explain the build-up of floodplain deposits.
3.. Explain how some rivers have been raised above the level of their floodplains.

Levee extension is one method of delta formation, levees extend out to sea and overbank deposits build up the delta. Channels can split as sediment builds up in the channel (channel bifurcation) and this repeated spliting of channels can form a bird's foot delta.

REJUVINATED RIVER PROFILE



RIVER TERRACES



Q

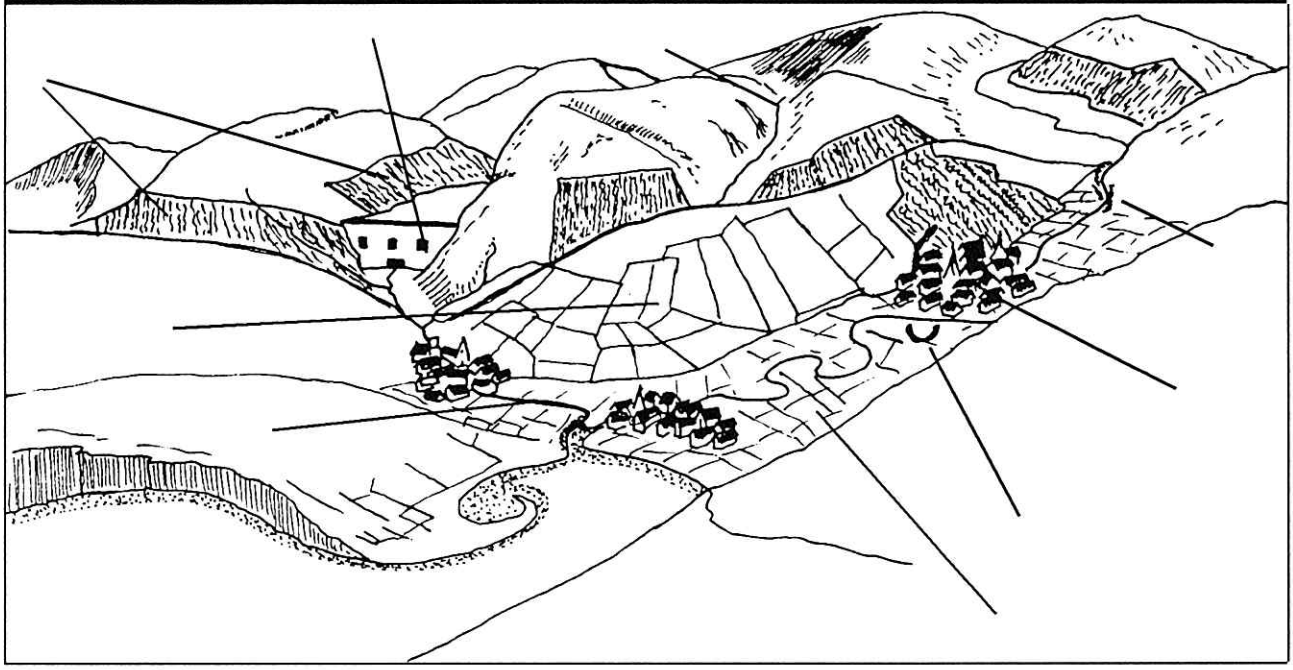
1.. Draw a diagram similar to the river profile diagram above, which shows a river with several knickpoints.
2.. Explain the formation of river terraces.
3.. Draw diagrams to illustrate the difference between incised and ingrown meanders.
4.. What is the lower limit below which a stream cannot erode?
5.. Explain the role of the ice ages in rejuvination.
6.. What will happen at the mouth of a river if relative sea level rises?

7.. Write a description for each of the terms listed in the box below.

gully	**river capture**	**misfit stream**	**elbow of capture**	
wind gap	**subsequent stream**	**superimposition**	**ria**	
stepped terrace	**rapid**	**gabions**	**revetments**	**natural bridge**

8.. Choose a map extract such as that for Stirling or Perth and identify any river features on the map giving six figure grid references.

River Basin modification



Q

1.. Landscape and the hydrological cycle are often altererd by human activity.
Add the following labels to the diagram above which shows some of the natural and human-induced changes in the landscape:

Run-off affected by forestry	**River flow interupted by dam**	**Run-off altered by field drainage**	**Run-off changed by urban area**
River has changed course	**River floodplain**	**Valley being widened by lateral erosion**	**Straightening of river course**
Headward erosion			

2.. Which of the above landscape changes are natural and which are human-induced?

3.. Comment on the advantages and disadvantages of the human-induced changes in a river basin. You may refer to examples you have studied.

4.. Choose one of the natural changes in the landscape and with the aid of diagrams explain how the landscape has changed.

Research Questions

1.. Find out about the impact of pollution on the Rhine river basin.

2.. Find out about the ways rivers can be modified by human engineering.

3.. Make a list of as many human activities as you can which interfere with the natural hydrological cycle.

HYDROSPHERE

1(a) Describe the 'V' shaped river valley system as illustrated in the diagram opposite.

(5)

and either

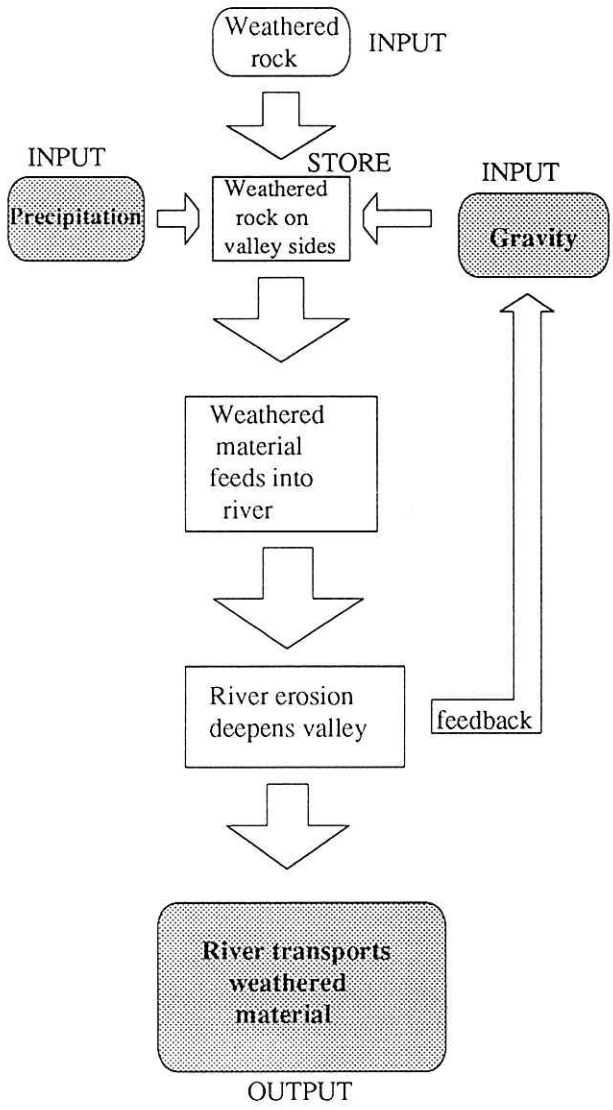
(b) Explain the factors which influence the shape of different 'V'shaped valleys.

(4)

or

(c) Explain the relative contributions of **slope processes** and **river erosion** in forming a 'V' shaped valley. You may illustrate your answer with a diagram.

(4)



The 'V' shaped river valley system

2 (a) Describe and explain the **transfers of water** in the hydrological cycle.

(6)

and either

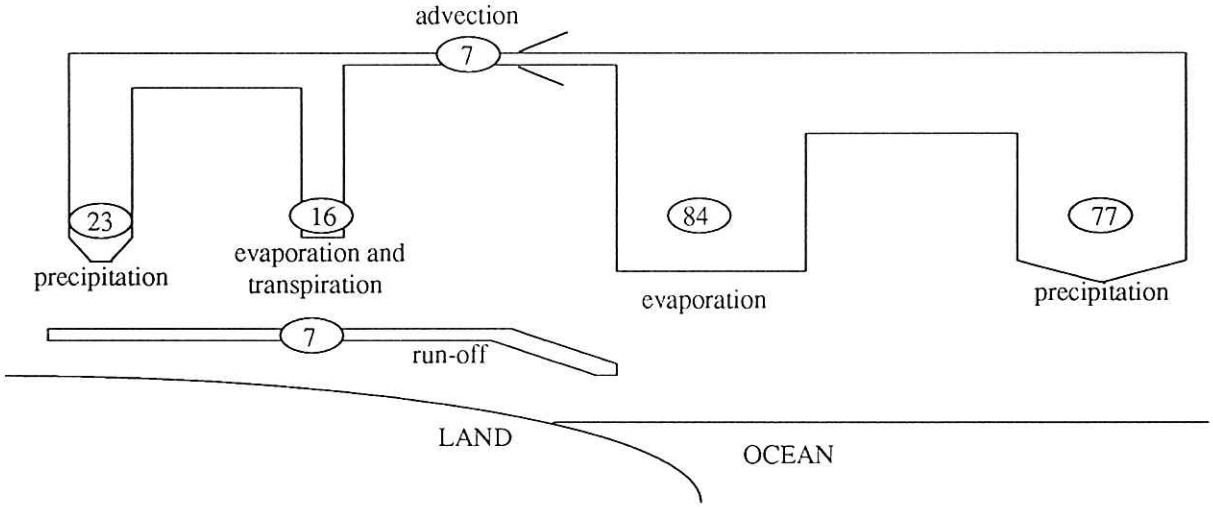
(b) List the main **stores of water** in the hydrological cycle indicating their relative importance.

(3)

or

(c) Give three examples of how human activity can **interupt or modify** the hydrological cycle.

(3)



Water transfer in the hydrological cycle (Figures refer to percentages of water in the hydrological cycle)