DP IB Geography: SL

Your notes

Drainage Basin Hydrology & Geomorphology

Contents

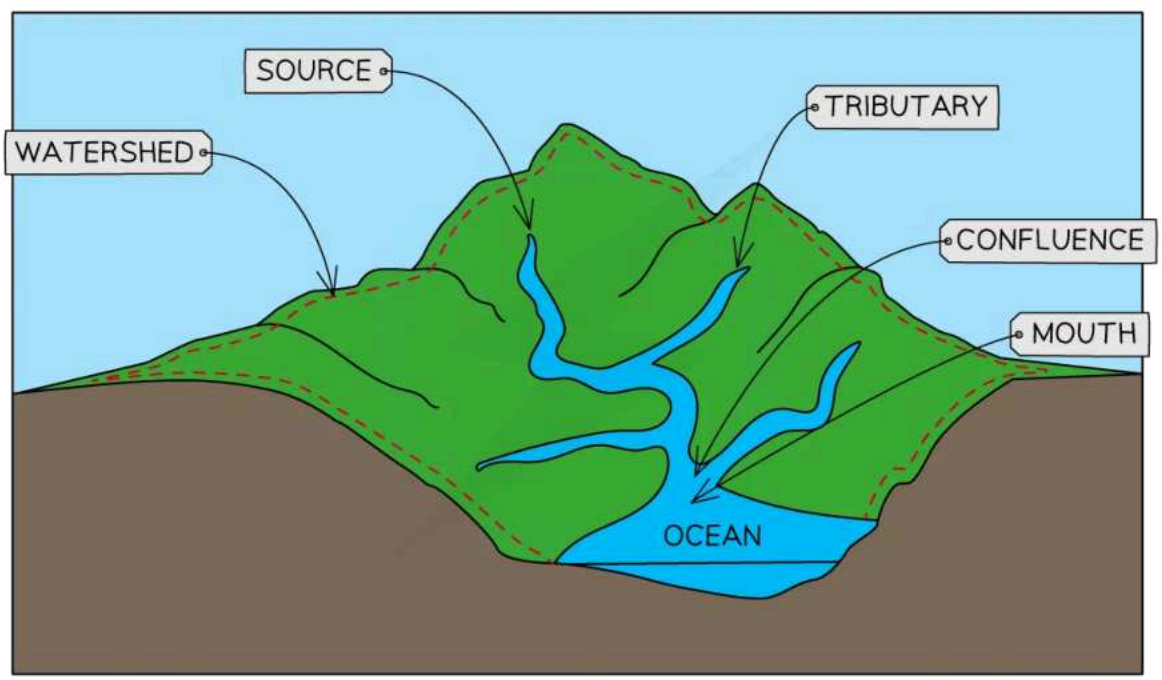
Drainage Basin System

Your notes

Drainage Basin System

- **Drainage basins** are areas of land where precipitation (rain or snow melt) drains downhill into a body of water such as a river, lake, wetland or ocean
- Drainage basins are **open systems** with inputs, transfers and outputs
- Features of a drainage basin include:
  - **Watershed**
  - **Source**
  - **Tributary**
  - **Confluence**
  - **Floodplain**
  - **Mouth**

Diagram showing the features of a drainage basin



Drainage basin features

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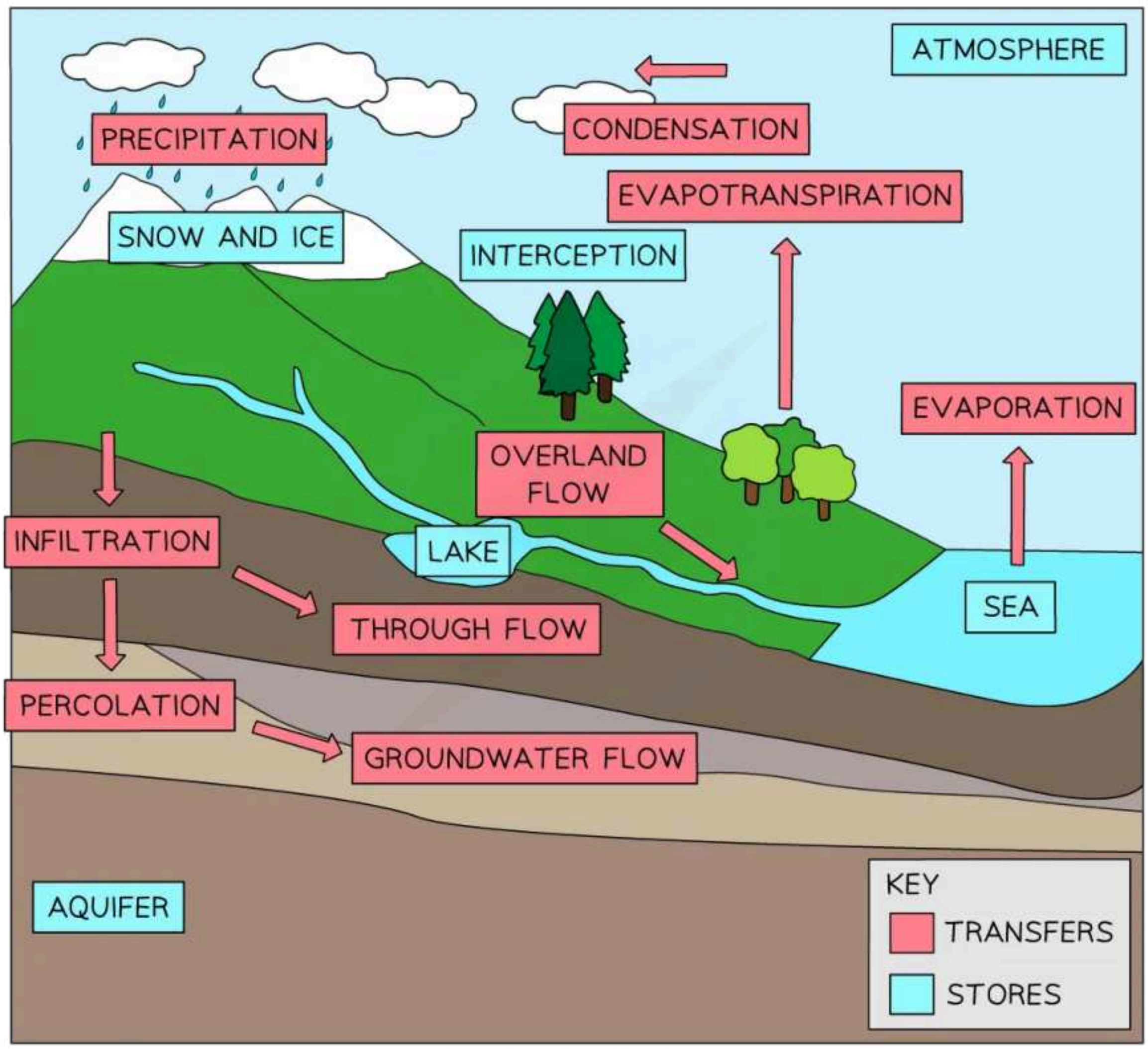
- After falling as precipitation, water can take many different routes before it reaches its end point
- Water can be stored in the system for a few days, years or centuries in aquifers

Diagram of the hydrological cycle



The hydrological cycle

Inputs, Flows, Outputs and Stores in the Drainage Basin

Inputs	Flows	Stores	Outputs
Precipitation	**Throughflow** **Surface run-off (overland flow)** **Groundwater(base) flow** **infiltration** **Percolation**	**Cryosphere** **Channel stores** **Vegetation** **Soil** **Aquifers** **Atmosphere as water vapour**	**Transpiration** **Evaporation** **Sublimation**

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Inputs

- **Precipitation** is the primary input into the drainage basin
- Precipitation is rainfall, snow, frost, hail and dew
- Key characteristics of precipitation impacting local **hydrology** (movement of water) include:
  - Total amount of precipitation
  - Intensity
  - Type (e.g. snow or rain)
  - Geographic distribution
  - Variability

Flows

Infiltration

- Infiltration is the process where water permeates, or is absorbed by the soil
- **Infiltration capacity** is the maximum rate at which rain can be absorbed in a given condition
- Infiltrated water becomes chemically enriched as it collects minerals and organic acids from vegetation and soil
- Plant roots create fine channels for percolation known as **percolines**

Surface runoff

- **Overland flow** (surface runoff) occurs when precipitation exceeds the infiltration rate or when the soil becomes saturated
- High precipitation intensity and low infiltration capacity lead to common surface runoff in areas like semi-arid regions and cultivated fields
- Surface flow happens near streams and river channels
- Throughflow refers to water moving naturally through soil pipes and percolines
- **Base flow** is the constant part of a river's discharge supplied by groundwater seepage into the riverbed, which slightly increases after wet periods

Stores

Vegetation

- Vegetation interception is when water remains on the surface of the leaves before evaporation
- Interception loss varies based on vegetation type
- Coniferous trees intercept more water in winter
- Deciduous trees intercept more water in summer

Soil

- **Soil moisture** is subsurface water within the soil
- **Field capacity** is the retained water level after excess drainage and near saturation
- **Wilting point** is the moisture range causing permanent plant wilting and setting plant growth limits

Aquifers

- Aquifers serve as significant water reserves
- Water in aquifers moves slowly and absorbs rainfall that would otherwise rush into streams
- Aquifers help maintain stream flow during extended dry spells
- Aquifers can lead to springs, which can become the source of streams or rivers
- **Groundwater** is subsurface water that percolates slowly into the rock beneath the soil
- Percolation speed depends on rock permeability
- Carboniferous limestone and chalk percolation speed can be relatively fast
- The permanently saturated zone in rocks and sediments is the **phreatic zone**

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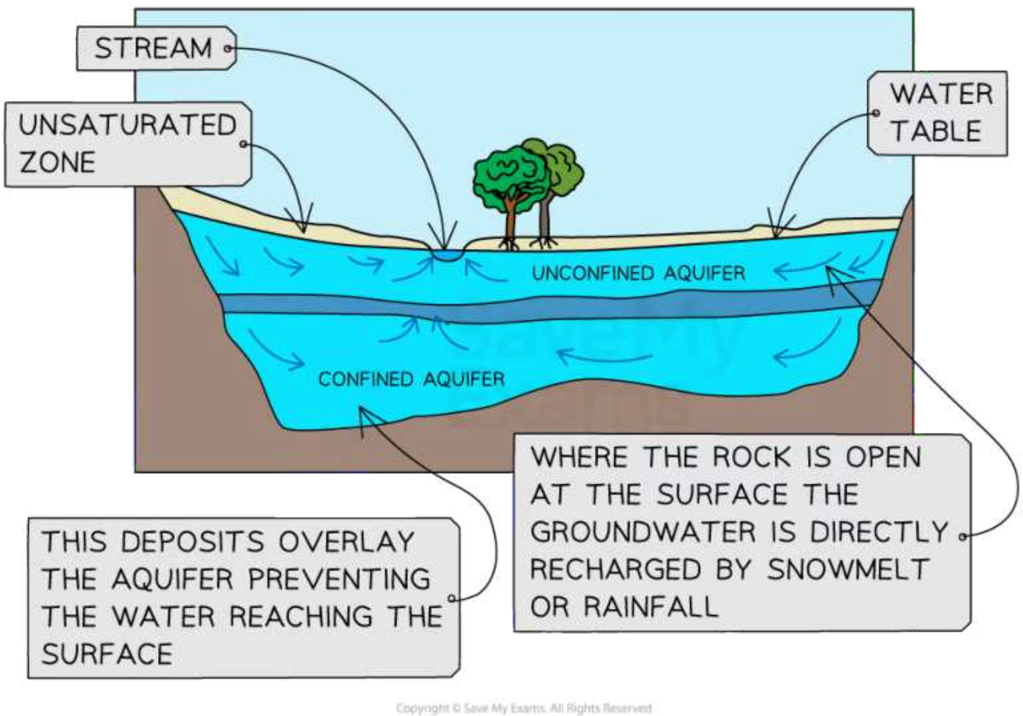
- The upper layer is known as the **water table**
- Seasonally variability: aquifers are higher in winter due to increased precipitation
- The seasonally wet and dry zone is called the **aeration zone**
- Groundwater accounts for 96.5% of all freshwater on Earth but it can take up to 20,000 years to recycle

Aquifer



Aquifer

Groundwater recharge

Type of recharge	How groundwater recharges
Infiltration	Through total precipitation at ground surface
Seepage	Through banks and beds of surface water
Leakage and inflow	From adjacent rocks and aquifers

Artificially	From irrigation and reservoirs

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Cryosphere

- The **cryosphere** includes Earth's snow and ice
- It contains up to 66% of the world's freshwater
- Over 97% of Earth's water is salty and freshwater resources are limited
- High-latitude and high-altitude regions store significant snow and ice
- Seasonal melting plays a key role in altering the basin's hydrological cycle

Outputs

- Evaporation is the conversion of liquid or solid substances into a gas
- Evaporation:
  - Involves the transformation of precipitation into water vapour in the atmosphere
  - Is most prominent over oceans and seas and is influenced by climatic conditions
  - Increases under warm, dry conditions
  - Decreases under cold, calm conditions
- Factors affecting evaporation include:
  - Temperature
  - **Humidity**
  - Wind speed
  - Availability of water
  - Vegetation
  - Surface colour

Evapotranspiration

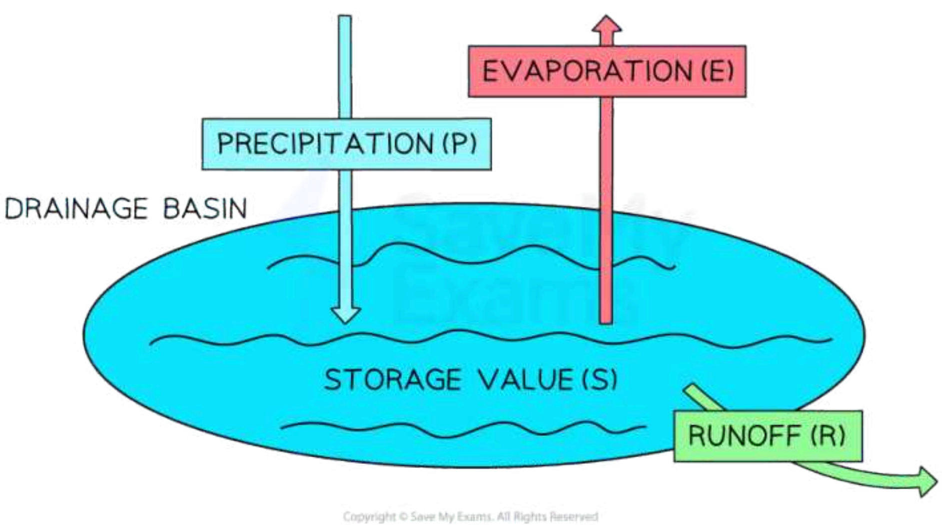
- Transpiration is the release of water vapour from living plants through their leaves and into the atmosphere
- **Evapotranspiration (EVT)** represents the primary source of water loss
- EVT accounts for nearly 100% of annual precipitation in arid areas and 75% in humid regions

- Evaporative losses can occur over ice and snow fields, barren rock slopes, desert areas, water surfaces and bare soil
- Potential evapotranspiration is determined by the availability of moisture.

The water budget

- Water budgets are the annual balance between inputs and outputs
- Water budgets can impact **soil water** availability
- The balances can be calculated at various scales, from global to local
- Water budgets at the regional level tell us the amount of water that is available for human use
- On a local scale, the water budget can tell us how much water is available in the soil

Diagram showing the water budget



Water budget

- The water budget uses the following equation: **P + Qin = ET + ΔS + Qout**
- P = precipitation (rain, snow, etc.)
- Qin = water flow into the watershed
- ET = quantity of evapotranspiration from soils, surface water, plants, etc.
- ΔS = Change in water storage
- Qout = sum of water flowing out of the watershed

Factors influencing the water budget

Factors that can affect the water budget	How the water budget is affected
Permeable rocks and porous soils	Encourage infiltration and percolation, which means the flow is slowed down and there is an increased storage in the water basin
Dense forests	Intercept rainfall, absorbing water through the canopy
Shape, relief and size of drainage basin	Influence amount of water flowing overland
Vegetation density	Affects patterns of water flow and stores in the basin
Seasonality	There will be more water in wet seasons, which will create a water surplus
Climate	Determines the amount and type of precipitation that transfers through a river basin

River Discharge & Channel Characteristics

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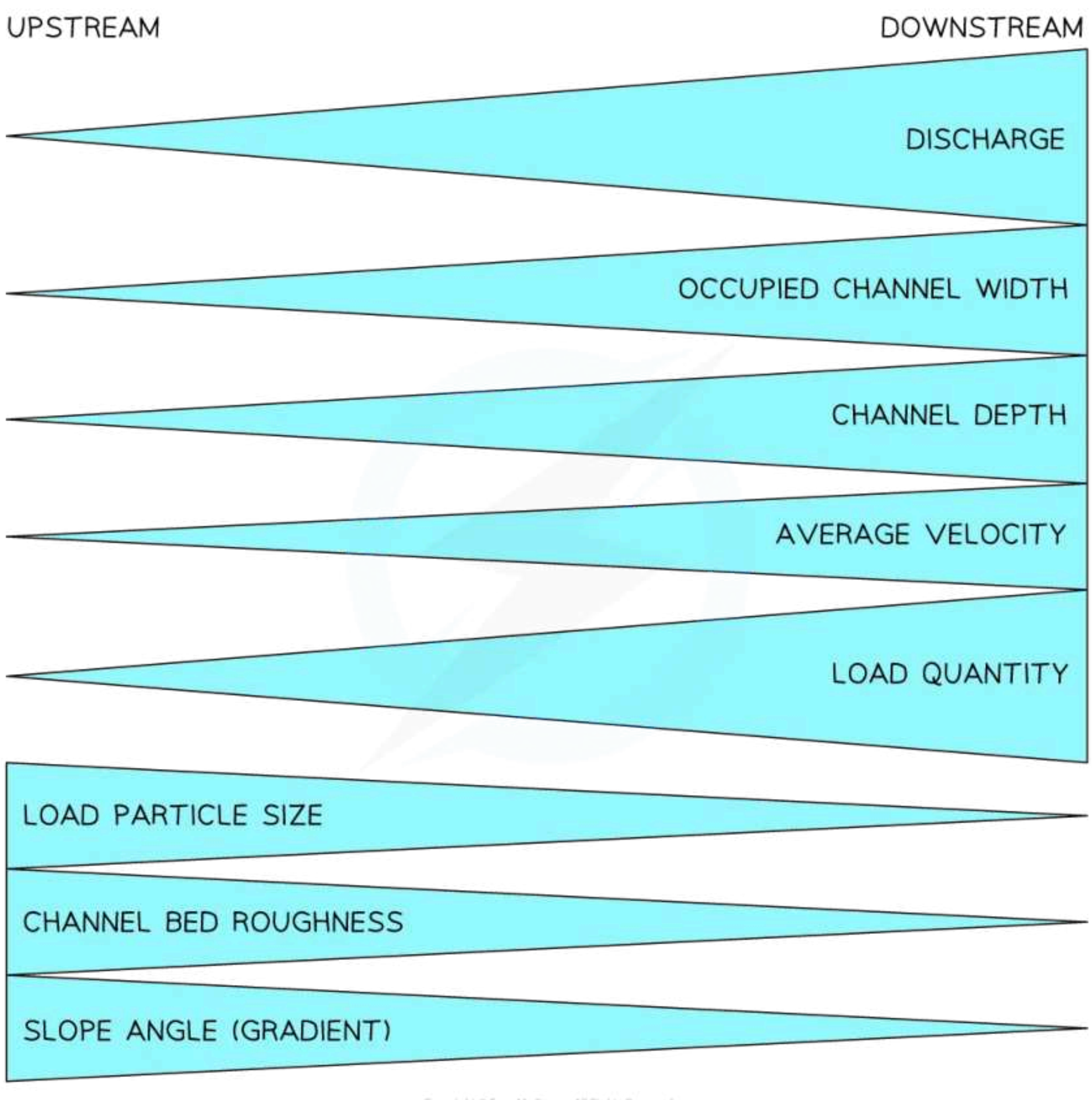
River Discharge & Stream Flow

- River discharge is the volume of water passing a given point over a set time
- As rivers move downstream the characteristic features change

Bradshaw model



Bradshaw model

River Channel Characteristics

Component	Definition
Discharge	The volume of water passing a specific point in the river per unit of time increases downstream due to tributary contributions
Occupied channel width	The width of the river channel typically increases downstream as more water from tributaries is added
Channel depth	The depth of the river channel increases downstream as more water accumulates
Average velocity	The speed at which water flows within the river generally increases downstream with a greater volume of water and steeper gradients
Load quantity	Load quantity increases as the material is made smaller through erosion
Load particle size	Load particle size becomes smaller as the material is made smaller through erosion
Channel bed roughness	Channel bed roughness decreases as the river's energy decreases allowing for accumulation of finer sediments leading to a smoother channel downstream
Slope angle	The slope angle decreases as a river moves downstream
Hydraulic radius	A cross-sectional area of the flow divided by the wetted perimeter

How to measure discharge in a river

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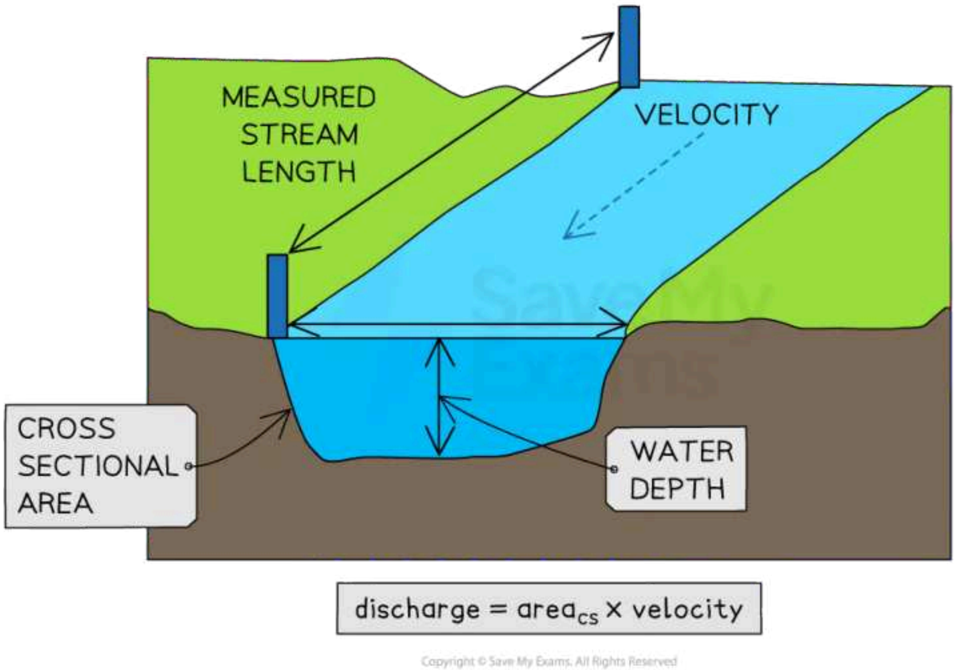
Your notes



Measuring river discharge

Worked Example

Calculating Discharge

Step One-Depth

- Calculate the mean depth
- All units of measurement should be the same
- The mean depth should be calculated in meters not centimetres

Depth measurements for Site One

	1	2	3	4	5	6	7	8	Mean
Depth in mm	0.05	0.12	0.17	0.23	0.30	0.35	0.28	0.18	0.21

- To calculate the mean depth add the 8 measurements together and divide by 8
- This gives a measurement of mean depth = 0.21m

Step Two-Cross-sectional area

- Cross-sectional area (m^2) = width (m) x mean depth (m)

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- If the width is 4mx mean depth 0.21m the cross-sectional area = 0.84m^2

Step Three – Velocity

Time Measurements for Site One

Time Measurement	Left	Center	Right
1st	35	28	37
2nd	42	30	39
3rd	36	27	45
Mean	37.7	28.3	40.3

- To work out the mean time taken for the float to travel 10 metres for site one the following calculations need to be completed:
  - 37.7+28.3+40.3–106.3
  - 106.3 is then divided by 3 (number of positions) to give a mean time for site one of 35.43 seconds
  - Divide this by 10 to get the velocity in m/s
  - 35.43/10=3.543 seconds
  - The surface velocity for site one is 3.543 m/s

Step Four-Discharge

- **Discharge = Cross-sectional Area 0.84m^2x Velocity 3.543 m/s**
- Discharge = 2.98 m^3/s (cumecs)

Factors affecting stream flow

- **Hydraulics** is the study of water flow in channels
- **Water flow** is determined by gravity and frictional resistance with the channel bed and banks
- Channel volume and shape affect the stream's energy
- When water flow is turbulent there will be **eddying** patterns
- Turbulence supports the lifting and suspension of fine particles
- Turbulent flow conditions include complex channel shapes, high velocities and **cavitation**
- **Laminar flow** is characterized by smooth and layered movements and is common in groundwater and glaciers but not in rivers
- Laminar flow occurs in shallow, smooth, straight channels with low velocities
- Rivers sediments remain undisturbed on the bed under laminar flow conditions

- When water velocity is low turbulence is reduced
- When water levels rise the mean velocity and the hydraulic radius enable the stream to appear to be more turbulent

Velocity

- Friction causes uneven velocity distribution in a stream
- The water closest to the bed and banks moves slowly
- Water in the centre of the channel travels the fastest
- Maximum velocity occurs mid-stream, about one-third down
- Channel shape influences the velocity

Channel shape

- Stream efficiency is measured using hydraulic radius (cross-sectional area divided by wetted perimeter)
- Higher ratios indicate greater efficiency and less frictional loss
- Channel shape is influenced by both channel material and river forces
- Solid rock leads to slow changes and **alluvium** allows rapid changes
- Silt and clay create steep, deep, narrow valleys, while sand and gravel promote wide, shallow channels

Channel roughness

- Channel roughness introduces friction, reducing water velocity
- Friction arises from bed irregularities, boulders, trees, vegetation and water-bed and bank contact
- Manning's n is a formula describing the relationship between channel roughness and velocity

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River Processes

Your notes

River Erosion

- **River erosion** is the wearing away of land as water flows past the bed and banks
- Erosion by rivers also provides material, which is carried down the river
- A river channel is eroded by:
  - **Vertical erosion** – the cutting down of the river into the bed and deepening the channel
  - **Lateral erosion** – the cutting in of the river to the bank and widening the channel

Four Methods of River Erosion

Erosional term	Definition
Hydraulic action	The force of the air and water into cracks in the river banks and beds
Attrition	The wearing away of the load as rocks knock against each other, making them smaller and rounder
Abrasion or corrasion	The scraping away of the bed and banks by material transported by the river
Solution or corrosion	Chemicals in the river dissolve minerals in the rocks within the bed and bank, carrying them away in solution

Methods of erosion

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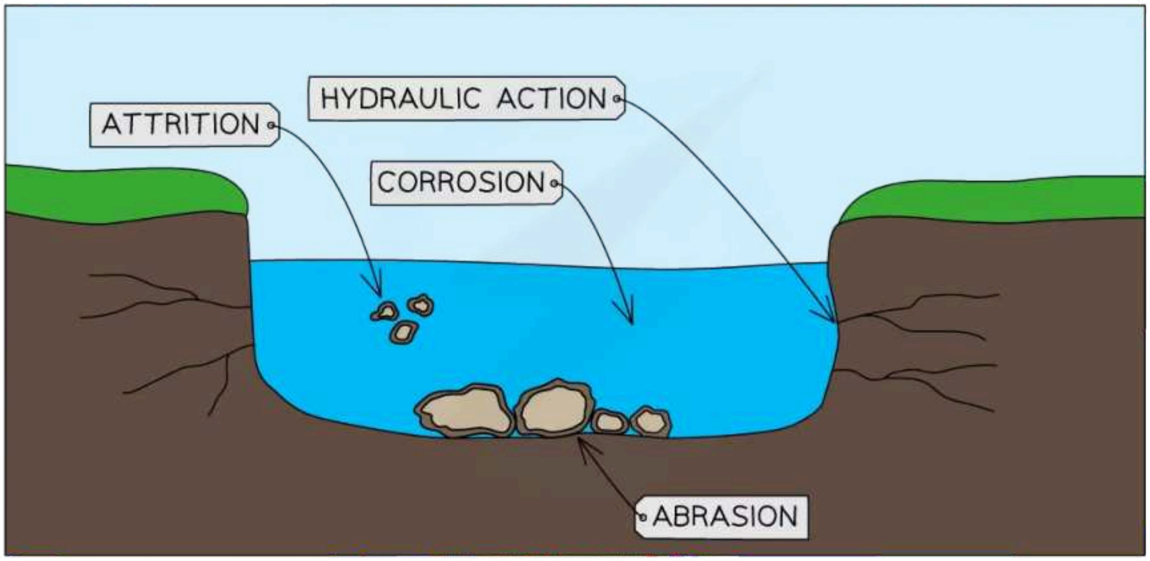
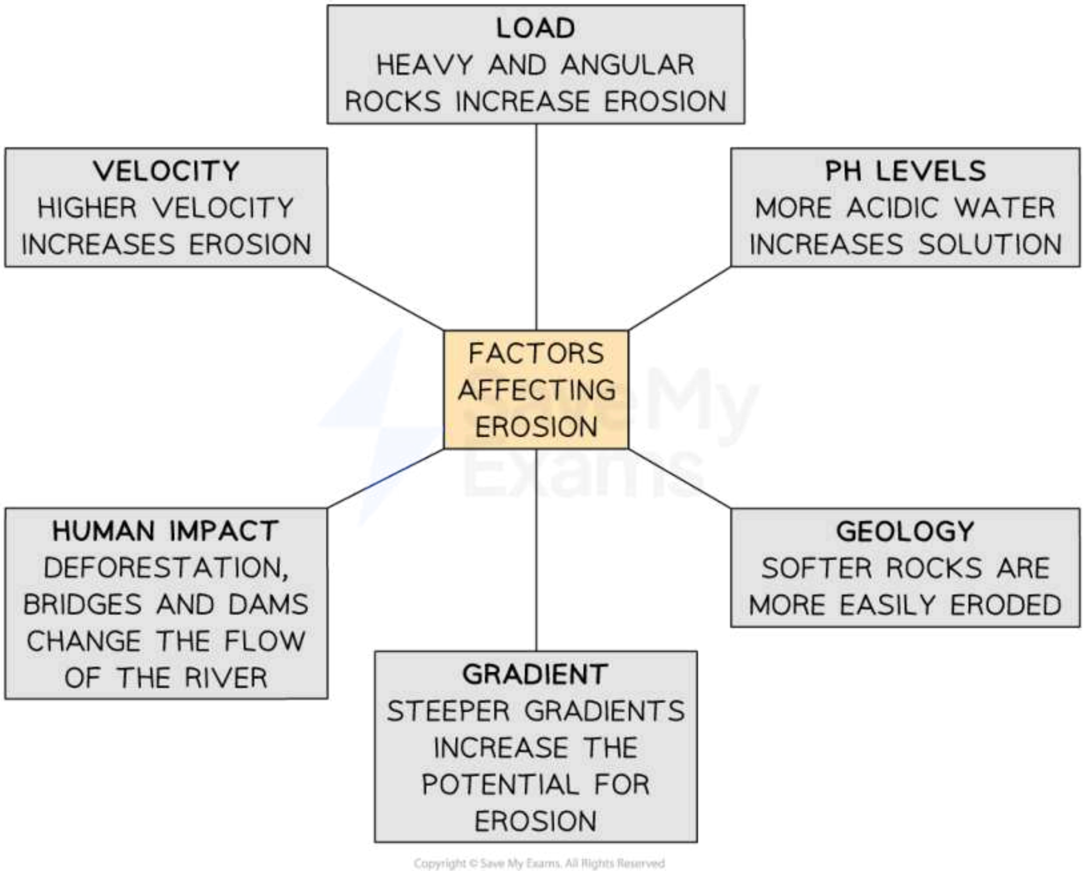


Methods of erosion

Factors affecting rates of erosion



Factors affecting the rate of erosion

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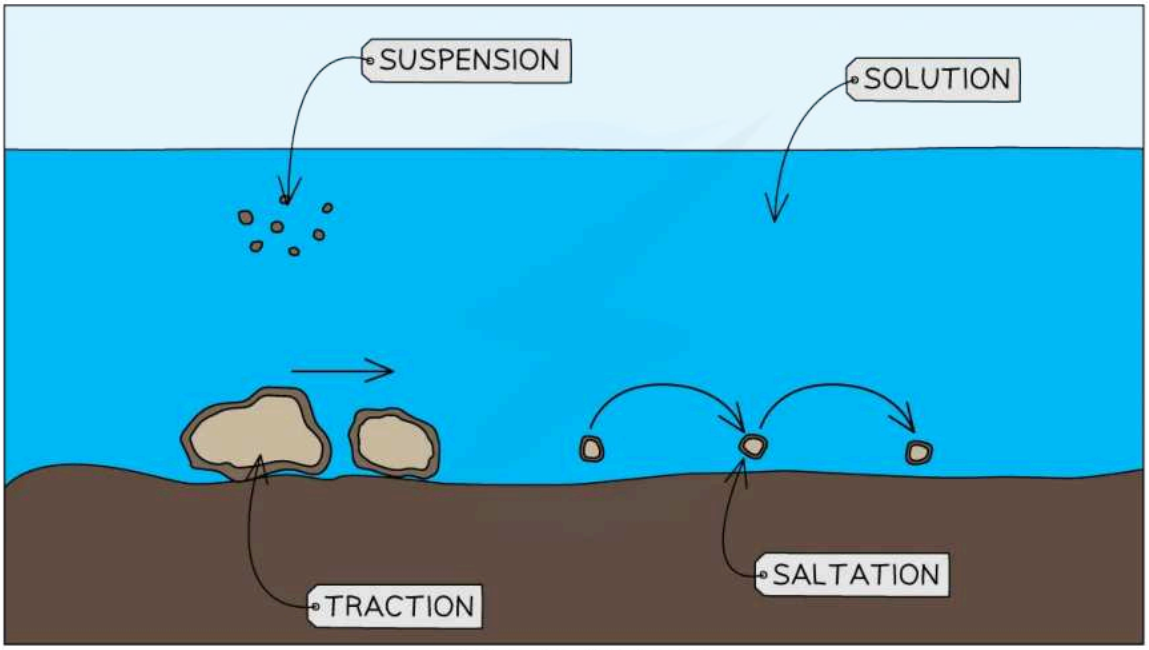
River Transportation

- There are five processes of transportation
  - **Suspension**
  - **Saltation**
  - **Traction**
  - **Solution**
  - **Floatation**

Your notes



Types of Transportation

- The load of a river changes with **discharge** and **velocity**
- **Stream capacity** is the maximum amount of debris a stream can carry.
- **Competence** is the diameter of the largest particle carried
- **Critical erosion velocity** is the minimum velocity to move grains of a specific size
- The relationship between velocity and discharge is illustrated by a **Hjulström curve**
- There are three important features of the Hjulström curve:
  - High velocities are required to lift particles
  - Higher velocities are needed for **entrainment** compared to transport
  - When velocity falls below a certain level (settling velocity) particles are deposited

The Hjulström curve

IMAGE TO BE INSERTED HERE

The Hjulström curve illustrates the relationship between velocity and efficiency. It shows the velocities at which sediment will normally be eroded, transported or deposited

River Deposition

Deposition

- Deposition can take place for a number of reasons:
  - A decrease in the volume of water
  - A shallow gradient that decreases velocity
  - An increase in friction between water and the channel

Braided channels

- Braided channels exhibit dynamic river environments
- Common in glacial rivers and arid regions
- Experience rapid changes in discharge, flow velocity and sediment processes
- Arid areas face flash floods, which cause erosion and sediment transport
- Glacial regions undergo surges and **diurnal** flow variations
- During peak flow, the erosion and transport processes dominate
- River braids merge and deposits are eroded
- Slower flow periods emphasise deposition
- The river divides into smaller braids.

Seasonality

- River processes vary seasonally
- Monsoonal rivers erode and transport more sediment during the wet season
- Some rivers experience high spring flow due to snowmelt, such as those in Iceland

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River Landforms

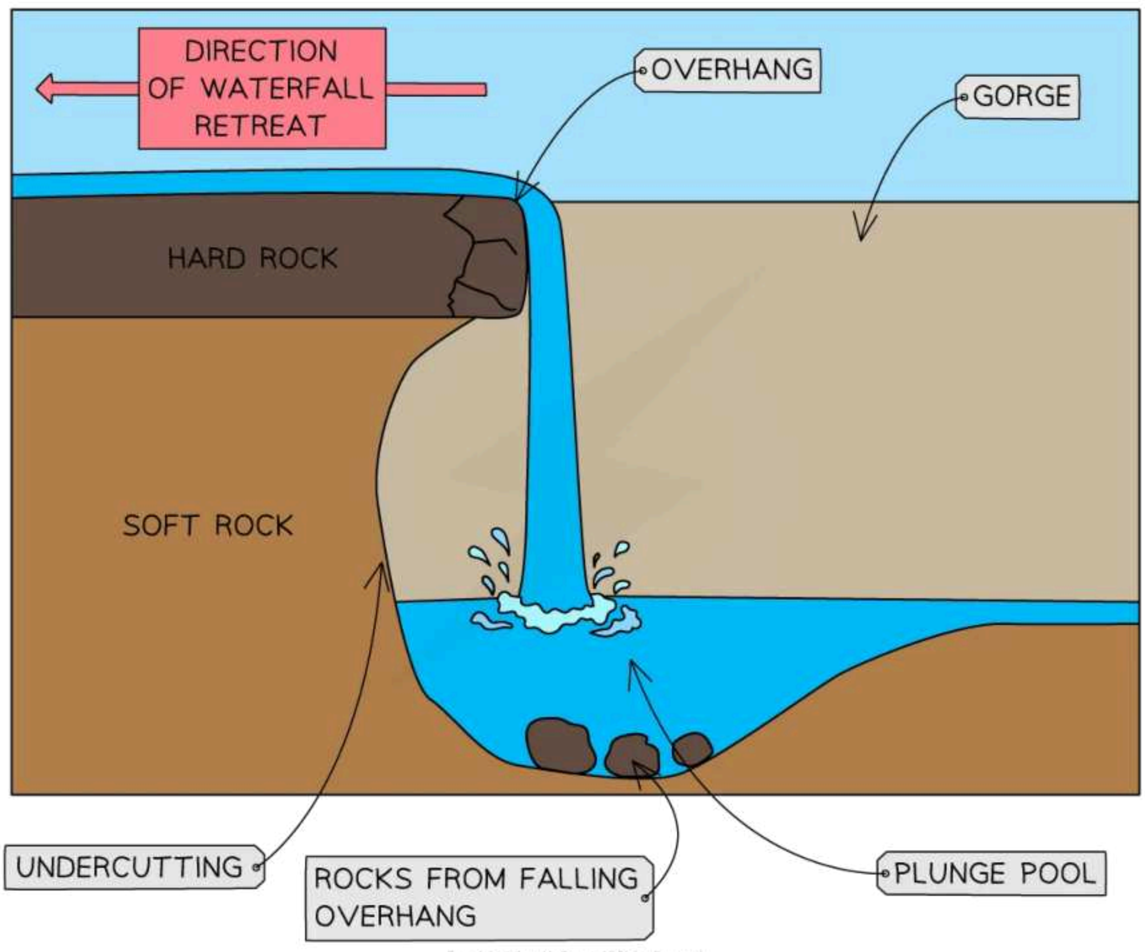
Your notes

Upper Course Landforms

Waterfalls

- Occur on horizontally bedded rocks
- Soft rock is undercut by hydraulic action and abrasion
- Due to the weight of the water and no support, the waterfall collapses and retreats upstream
- Over thousands of years, waterfalls may create a gorge

Formation of a waterfall



The formation of a waterfall

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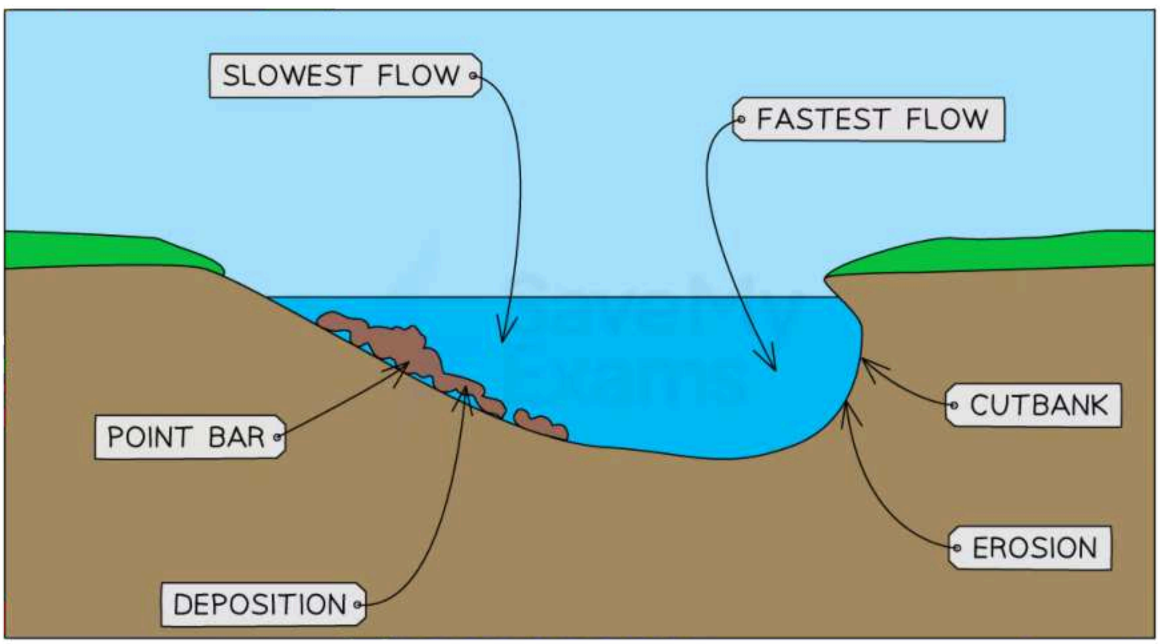
Middle & Lower Course Landforms

Meanders

- Meanders are formed in rivers due to the combination of erosion and sediment deposition processes
- The river erodes the outer bank of a bend, creating a cutbank
- Deposition occurs along the inner bank, forming a **point bar**
- As the water flows faster along the outer bend (cutbank) it erodes the bank more, deepening the channel
- Sediment is deposited along the inner bend (point bar), causing the bank to build up
- Over time, erosional and depositional processes cause the river to develop a **sinuous**, meandering course

Cross-section through a meander



Meander formation

Floodplains

- When a river floods, a floodplain is formed

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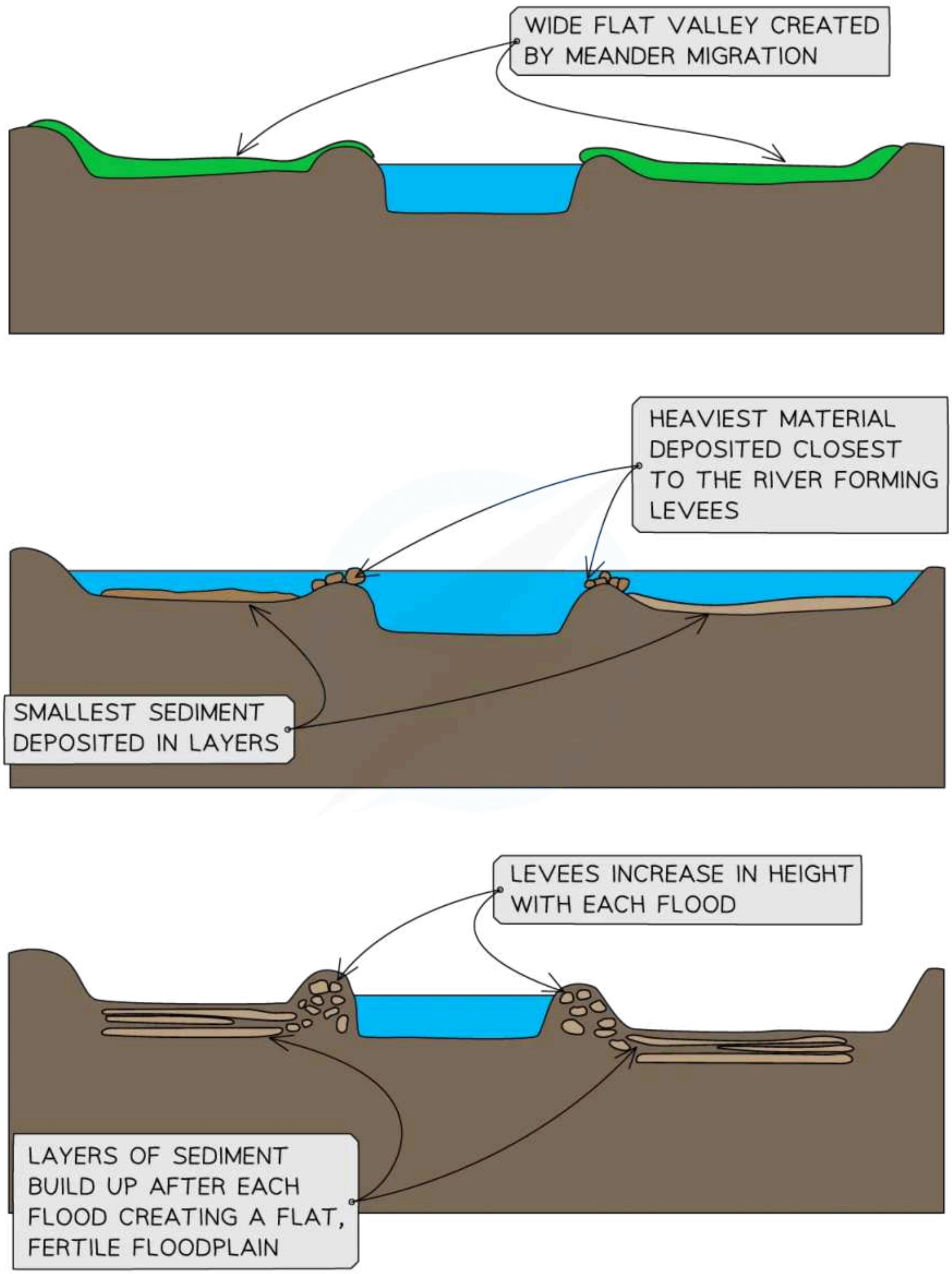
- Alluvium is a mixture of sand and gravel that is eroded on the outside of the meander
- Floodplains are built up by channel deposition
- Floodplains consist of finer materials

Levees

- A landform of deposition
- Levees are raised banks
- Coarse material is deposited near the channel
- Finer material is deposited and carried to the floodplain
- Levees are found on the edge of the river
- They are formed by repeated flooding
- When a river floods, the river's energy is reduced
- Coarse material is dropped first and then lighter material
- Over time, the levees build up from coarse material

Floodplain and levee formation


WIDE FLAT VALLEY CREATED BY MEANDER MIGRATION
HEAVIEST MATERIAL DEPOSITED CLOSEST TO THE RIVER FORMING LEVEES
SMALLEST SEDIMENT DEPOSITED IN LAYERS
LEVEES INCREASE IN HEIGHT WITH EACH FLOOD
LAYERS OF SEDIMENT BUILD UP AFTER EACH FLOOD CREATING A FLAT, FERTILE FLOODPLAIN

The formation of floodplains and levees

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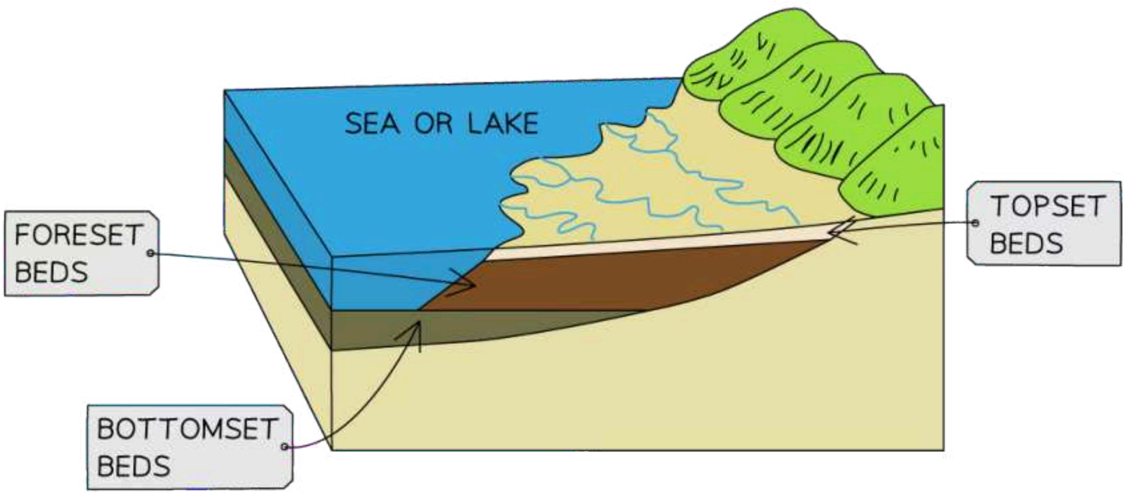
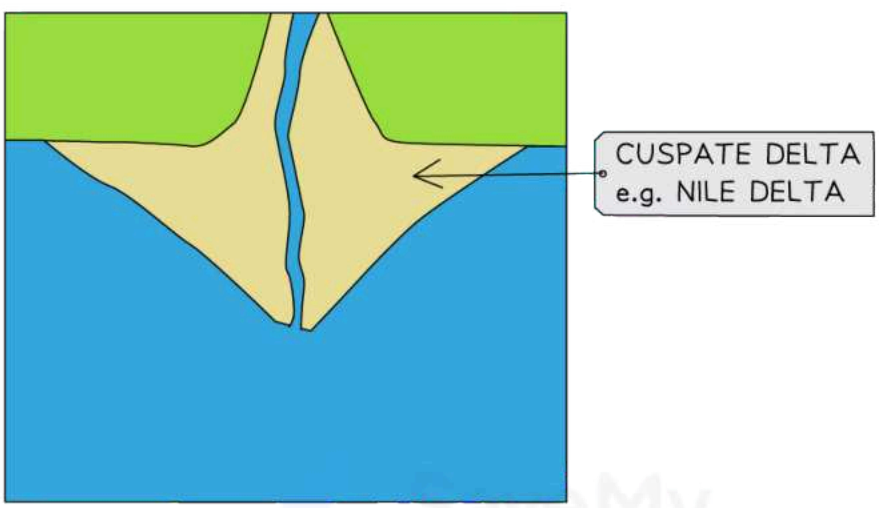
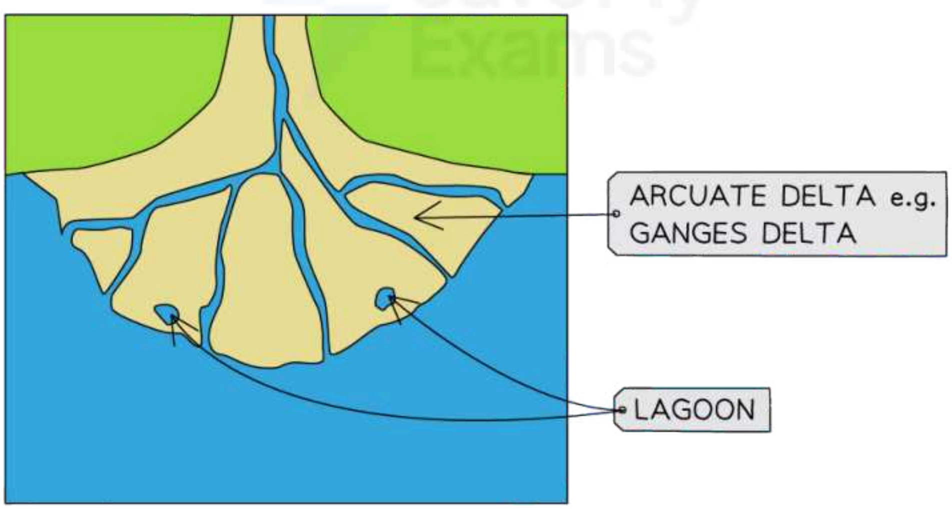
Deltas

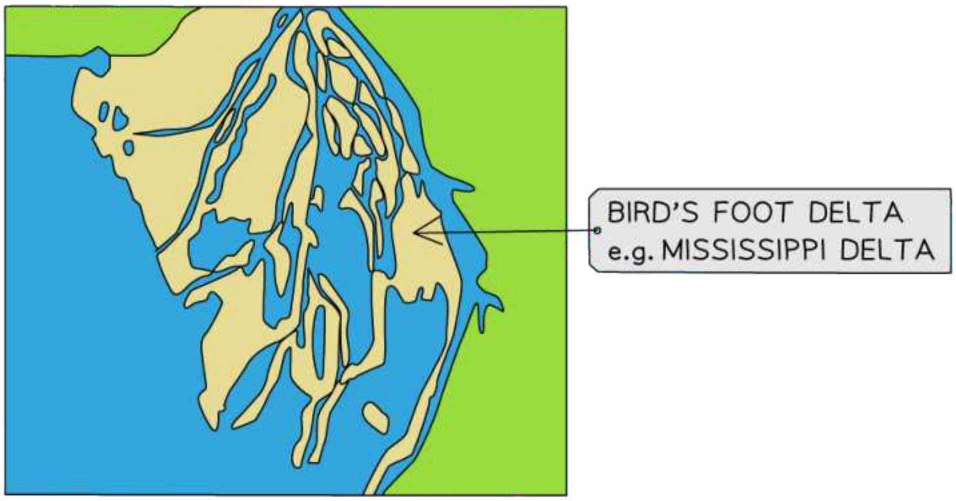
- Deltas are formed when streams flow into standing bodies of water
- Rivers must carry a large amount of sediment for deltas to form
- **Flocculation** increases deposition
- **Bioconstruction** increases deposition
- Delta formation must have a rapid drop in stream velocity
- There are a variety of delta formations, such as arcuate and bird's foot

Types of delta


SEA OR LAKE
FORESET BEDS
TOPSET BEDS
BOTTOMSET BEDS


CUSPATE DELTA e.g. NILE DELTA


ARCUATE DELTA e.g. GANGES DELTA
LAGOON



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