Geo Factsheet

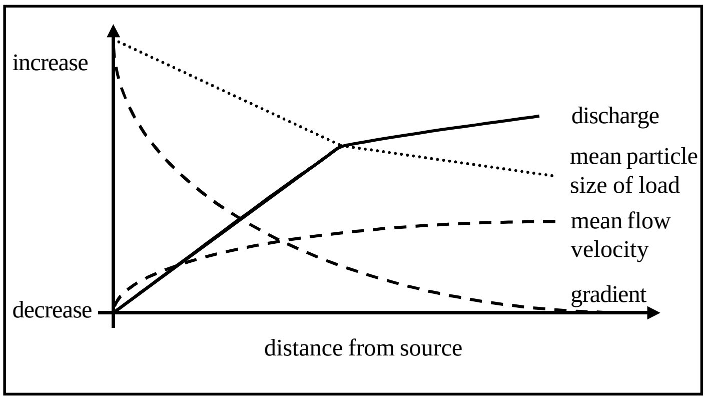
Number 98

Understanding River Channel Variables

This Factsheet will examine how and why discharge, velocity, gradient, and load change downstream in a river. It is particularly suitable for the new AS students

The variables of discharge, velocity, gradient and load interact in the river channels. A model of the downstream changes is shown in Fig. 1. It is a simplified version of **Schumm's** model There are many reasons why these relationships are not found in all rivers.

Fig. 1 Downstream changes in river variables



Discharge

Discharge is the volume of flow of water per unit time. It is often measured in cubic metres per second (known as cumecs). In general, discharge increases with distance from the source to the mouth of a river. More water from tributary streams, surface runoff, throughflow and baseflow enters the river.

> ***Exam hint:*** *Do not confuse discharge with velocity. You should define the terms before you use them in an answer.*

There are, however, several reasons why there is not a steady increase in discharge with distance from the source.

1. Characteristics of tributaries – the exact point of discharge increase depends on the point at which the tributary meets the main river.
2. Rock type and structure – the surface runoff component of discharge is lower in drainage basins of permeable rock than impermeable rock.
3. Land-use – discharge is higher in unvegetated, urbanised and deforested basins because there is greater surface runoff.
4. Direct human influences – Humans may add water to a river and increase the discharge (e.g. at a sewage outfall) or they can remove water and decrease the discharge (e.g. abstraction of drinking water).

Velocity

The velocity of a river refers to the rate of water movement. It can be measured in metres per second. Since velocity varies with depth and with distance from the banks, the mean flow velocity is calculated. Mean flow velocity increases slightly with distance from the source.

River velocity is determined by the efficiency of the river in overcoming friction with the bed and banks. Approximately 95% of a river's energy is lost to friction under normal flow conditions. Velocity increases as a river becomes more efficient in its lower course. There are two major reasons:

1. Hydraulic radius - the hydraulic radius of a channel is calculated by dividing cross-sectional area by wetted perimeter. The river is deeper, wider and has higher discharge in its lower course. It has a higher hydraulic radius than in the upper course. Relatively less water is in contact with the wetted perimeter.
2. Channel roughness – rivers do not have a smooth bank and beds. Where there are large rocks in the bed, energy lost to friction is increased. In the upper course, where erosion is dominant over deposition, angular boulders reduce the efficiency of the river. In the lower course, there is less resistance from the smooth silt and clay banks and bed.

Gradient

The gradient of a slope is its steepness. It is expressed as the ratio between vertical change over horizontal distance. For rivers, the gradient of the bed is most commonly measured. Gradient changes are found throughout a river's long profile.

The long profile of a river is a longitudinal section of the course of the river drawn along the **thalweg** (the line of maximum depth along the river channel) from source to mouth. It is drawn as a graph of distance from source (x-axis) against altitude (y-axis).

The ideal long profile for a river in a humid environment is a downward concave curve (see Fig. 1). There is a gradual decrease in slope gradient. The lowest level to which a river flows is called its base level. In practice, this is often sea level.

> ***Exam Hint:-*** *Strong candidates will be able to draw an annotated long profile of a located river. Figures for altitude and distance downstream are required. You can use an OS map to draw both long and cross profiles of a sample stream or river*

Changes in gradient are related to changes in discharge. Discharge is higher in the lower course. Since gradient decreases as discharge increases, a river can transport the same quantity and size of sediment load in the gentler lower course as it can in the steeper upper course.

Observations from rivers in arid environments provide more evidence for a strong negative correlation between discharge and gradient. These rivers have a downward convex long profile. Since there is a rapid rate of evaporation, the river experiences a net loss of discharge downstream. The steep downstream gradients are produced by deposition during rare flood events.

On a small scale, the long profile is punctuated by a series of pools and riffles. The gradient is steeper at riffles and gentler at pools. Gradient may also become steeper at **knickpoints**. A knickpoint is a discontinuity in the long profile where there is an increase in downstream channel gradient.

There are several causes of knickpoints:

1. Rejuvenation – this is caused by a fall in base level. Sea-level may fall in relation to the land (e.g. during a glacial) or the land may rise in relation to the sea (e.g. crustal uplift). As a result, the rate of vertical erosion increases. Initially the river will flow over cliffs in a waterfall into the sea. Over time, the waterfall is eroded backwards.
2. Confluence of tributaries –compared to upstream, there is a sudden increase in discharge downstream of the discharge. The rate of vertical erosion increases since the river has more energy.
3. Rock type and structure – most waterfalls are found where a river flows over rocks which have different levels of resistance to erosion. The river erodes weak rock more rapidly than a resistant rock. Rivers can exploit structural weaknesses, such as faults.
4. Changes in discharge and sediment load – a sudden increase can lead to increased vertical erosion. Both changes may occur naturally (e.g. river capture increases discharge in the master consequent river) or through human activity (e.g. afforestation of slopes reduces sediment load in the river).

Over time, alluvial channels will increase erosion at the knickpoint through an increase in river flow velocity. The knickpoint is therefore removed from the long profile.

Load

Load is the total mass of material transported by a river. The way in which material is moved depends on its size. There are downstream changes in the amount and the mean particle size of load. Table 1.

Table 1. Downstream changes in amount and mean particle size

Name of load	Type of particle	Diameter of particle	Method of transport
Bed load	Sand, pebbles and rocks	>0.1 mm	Saltation and traction
Suspended load	Clay and silt	0.001 – 0.1 mm	Suspension
Dissolved load	Soluble material	-	Solution

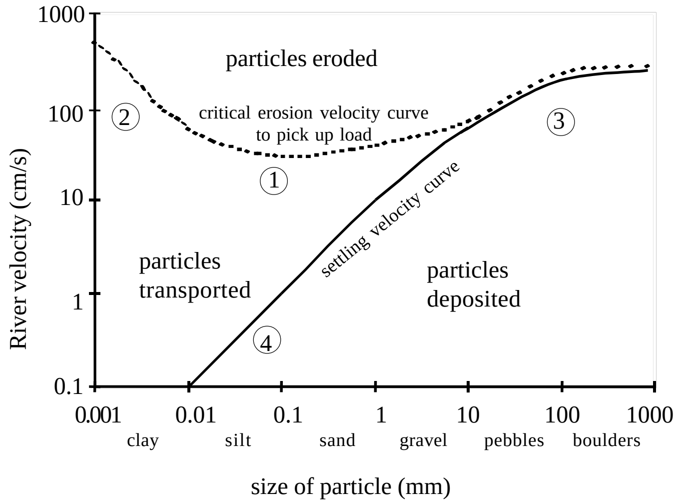
The **competence** of flowing water is the maximum particle size that can be transported. The **capacity** of a river is not the amount of water it contains (this is the discharge) but the maximum amount of load that can be transported.

***Exam Hint -** Examiners are impressed by precise terms. Instead of writing "transportation" or "erosion", try to use specific words, such as "saltation and corrasion".*

When the velocity is low, only fine particles like clay and silt can be transported. As the velocity increases, larger particles such as sand and pebbles can be transported. Therefore, a river's competence increases as its velocity increases.

The relationship between velocity and the size of particles transported is not a simple positive correlation. The Hjulström curve (Fig. 2) shows the relationship. The size of load increases with distance from the source as the river has more energy to transport material.

Fig 2. The Hjulström curve



Key
1. Silt/sand are picked up (**entrained**) at the lowest velocities.
2. Clays are as difficult to pick up as pebbles - although they are small particles they are very cohesive and the claybed is very smooth.
3. Large boulders are dropped very easily.
4. Clay particles can be transported in suspension at very low velocities.

***Exam Hint -** Questions on the Hjulström curve are often seen. Make sure that you understand how the critical erosion velocity curve and settling velocity curve work.*

Although there is an increase in mean flow velocity, the mean particle size decreases with distance downstream. This is not because the competence of the river has decreased. Instead smaller particles have become a relatively more important component of the load.

- Particles are eroded by attrition (collision with other particles), making them smaller and rounder. Attrition produces small particles of sediment. Abrasion produces small particles of sediment.

- The river sorts particles of different sizes. Smaller particles are carried at lower velocities. These particles remain in the water flow during periods of low flow when larger particles are deposited.

- The longer a particle has been in the river system, the longer that it has been made smaller by weathering. Particles can be stored on the floodplain, or in bars in braided channels, during periods of low flow. Given sufficiently long weathering time, the rock may disintegrate into its constituent grains when it re-enters the river.

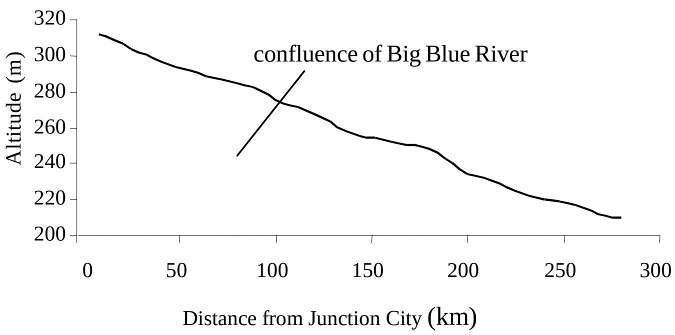
Particle size declines rapidly downstream in the upper course of a river, but it declines more slowly in the lower course. Particles are also rounder downstream as a result of attrition. There are two reasons why a downstream decrease in particles does not always occur: Particles transported by short tributaries may be less well sorted. Particles which reach the channel from landslides and human activity (e.g. mining spoil) may be large and angular.

Case Study – River Kansas, USA

The River Kansas begins at the confluence of the Rivers Republican and Smoky Hills at Junction City. It flows 272 km to a confluence with the River Missouri at Kansas City. The drainage basin of the Kansas covers 155 000 km².

There is a decrease in gradient over the length of the Kansas (Fig. 3).

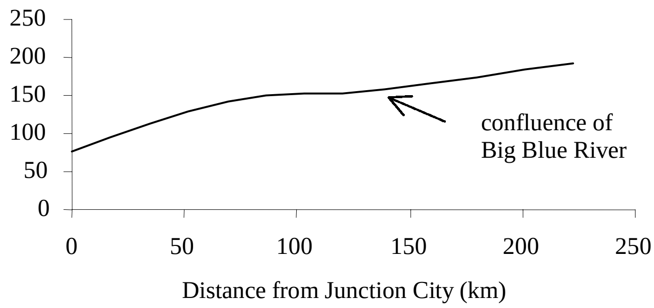
Fig. 3 Long profile of the Kansas



It starts at 320 m and falls steadily to 230 m over the next 250 km. In the last 22 km there is a slight steepening of the bed, so that the confluence is at 210 m A gradual drop in the level of the Missouri (0.6 m since 1940), which acts as a local base level for the Kansas, has rejuvenated the lower river.

Discharge increases gradually as more water enters the channel by overland flow, throughflow and baseflow. There are sharp increases in discharge downstream of major tributaries. As Fig. 4 shows, for example, mean monthly discharge doubles downstream of the confluence of Big Blue River.

Fig. 4 Mean monthly discharge 1967-96 of the Kansas



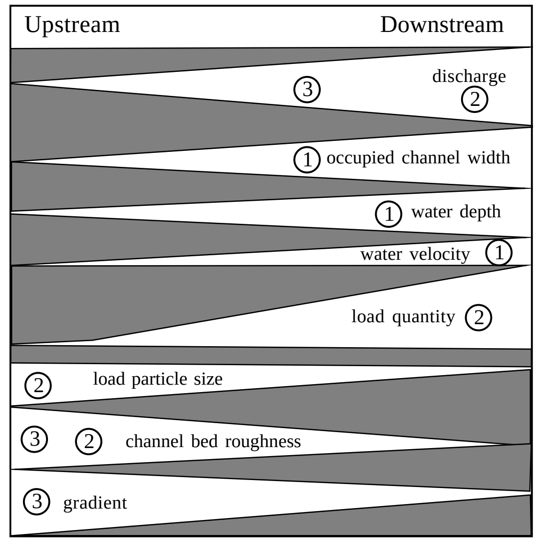
The capacity of the river increases with distance from Junction City. At Junction City, 1.26 million tonnes of sediment are transported per year. At Lecompton, 130 km. downstream, 1.37 million tonnes of sediment are transported per year.

The maximum size of particle that is normally transported by the Kansas is sand-sized. Gravel is only transported during floods. A lower proportion of the load is sand in the lower course of the river.

Practice Questions

1. (a) Describe and explain the factors that have affected the long profile of a river you have studied. *(10 marks)*
   (b) For a river you have studied, how and why does the composition of the load vary downstream? *(10 marks)*

2. Study the diagram of Brashaw's model of how river channel variables change downstream.



Key
1. Discharge linkages 2. Load linkages 3. velocity linkages

(a) Describe and suggest reasons for the changes in velocity. (6 marks)
(b) Explain why the discharge increases downstream. (7 marks)
(c) Suggest reasons for the increase in load quantity but the decrease in load particle size. (7 marks)

Answers

1. (a) This is a "factors" question, so it is useful to assemble a list of factors that affect the long profile. Remember to describe the effects of each factor and then explain each of these effects in turn. Able candidates should be able to draw the long profile of a river they have studied and suggest reasons for any knickpoints.

   (b) Again this should be well located. "How" means declining mean particle size, relatively more suspended load, relatively less bedload. "Why" means more erosion, sorting and weathering. The "how" section will probably be shorter than the "why" section, but they must both be included. Able candidates will describe and explain deviations from the expected pattern.
   Terminology to include - communication (decrease in size) attrition, index of wear/roundness
   - refer to the Hjulström curve to explain entrainment, transport and deposition.

2. (a) Hint - use the velocity linkages 3. - Note: the impact of decreased gradient is counteracted by decreased friction

   (b) Hint - Discharge is a function of both velocity and volume

   (c) Use linkages 2. Hint - for quantity think about the role of discharge, for size think about the process of attrition

Further research

- For more information on current research at the Kansas River http://www.kgs.ukans.edu/Publications/KR/
- Information on rivers in the UK http://www.environment-agency.gov.uk/envinfo/index.htm

Acknowledgements;
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