GEOACTIVE

538

Investigating downstream changes in river characteristics

By Robert Burn

A river investigation case study

The River Tillingbourne is a commonly studied river in southeast England. Geography students regularly examine the characteristics of the river and how they change as it flows downstream. This case study uses techniques and data collected by students to measure a range of these characteristics. These are then compared with a geographical model of changes expected in a river, called the Bradshaw model. The results are analysed and conclusions drawn to demonstrate the investigation from beginning to end. A final evaluation outlines some of the study's shortcomings. The activities serve as good practice for your own river investigation, or as a virtual visit to a river, to learn about how it functions using a more practical approach.

The case study covers river characteristics of:

- width, depth, velocity and discharge
- gradient, cross-sectional area and hydraulic radius.

Key vocabulary

source, gradient, cross-sectional area, velocity, discharge, tributary, hypotheses, friction

Learning outcome

At the end of this case study you will understand the process of a geographical investigation into river characteristics. You will see how a question and hypotheses can be used to give clarity to the process of comparing real world fieldwork data with a theoretical model. You will also see how information is collected, presented and analysed to find answers and to make suggestions for further investigation.

Relevance to specifications

AQA A	Unit 1: Physical Geography, Section B, Water on the Land, page 13 http://filestore.aqa.org.uk/subjects/AQA-9030-W-SP-14.PDF
Edexcel A	Unit 2: The Physical World, Section A, The Physical World, Topic 2, River landscapes, page 21 http://www.edexcel.com/migrationdocuments/GCSE%20New%20GCSE/9781446911907_GCSE_Lin_Geog_A_Issue_5.pdf
Edexcel B	Unit 1: Dynamic Planet, Section B, Small-scale Dynamic Planet, Topic 6, River Processes and Pressures, page 17 http://www.edexcel.com/migrationdocuments/GCSE%20New%20GCSE/9781446911914_GCSE_Lin_Geog_B_Issue_5.pdf
OCR B	Unit B563: Key Geographical Themes, Topic 2, Theme 1: River and Coasts, page 12 http://www.ocr.org.uk/Images/82581-specification.pdf
WJEC A	Unit 1: The Core, The Physical World, Theme 1, Water, page 14 http://www.wjec.co.uk/qualifications/geography/geography-gcse/16128.pdf?language_id=1
WJEC B	Unit 1: Challenges and Interactions in Geography, Theme 2: Physical Processes & Relationships Between People and Environments, River processes and landforms, page 18 http://www.wjec.co.uk/uploads/publications/17213.pdf?language_id=1
CCEA	Unit 1: Understanding Our Natural World, Theme A: The Dynamic Landscape, pages 8 and 9; a copy of the specification can be downloaded from: http://www.rewardinglearning.org.uk/microsites/geography/gcse/index.asp
Cambridge IGCSE	Theme 2: The natural environment, River processes, page 14 http://www.cie.org.uk/images/150857-2016-syllabus.pdf
Edexcel IGCSE	Section A, The natural environment and people, Topic 1, River environments, page 7 https://www.edexcel.com/migrationdocuments/IGCSE%20New%20IGCSE/IGCSE2009_Geography_(4GEO)_Specification.pdf

Investigating downstream changes in river characteristics

River environments are very good locations for physical geographical investigations. One of the most common forms of river investigation is to look for changes in the characteristics of a river as it progresses downstream.

Bradshaw's model

As a typical river flows from source to mouth it is believed to follow a predictable set of changes in a range of key characteristics, for example width, depth, gradient, cross-sectional area, water velocity and discharge. The Bradshaw model (Figure 1) predicts how these parameters are expected to change as you follow a river from source to mouth.

> "The Bradshaw model predicts how certain parameters are expected to change as you follow a river from source to mouth."

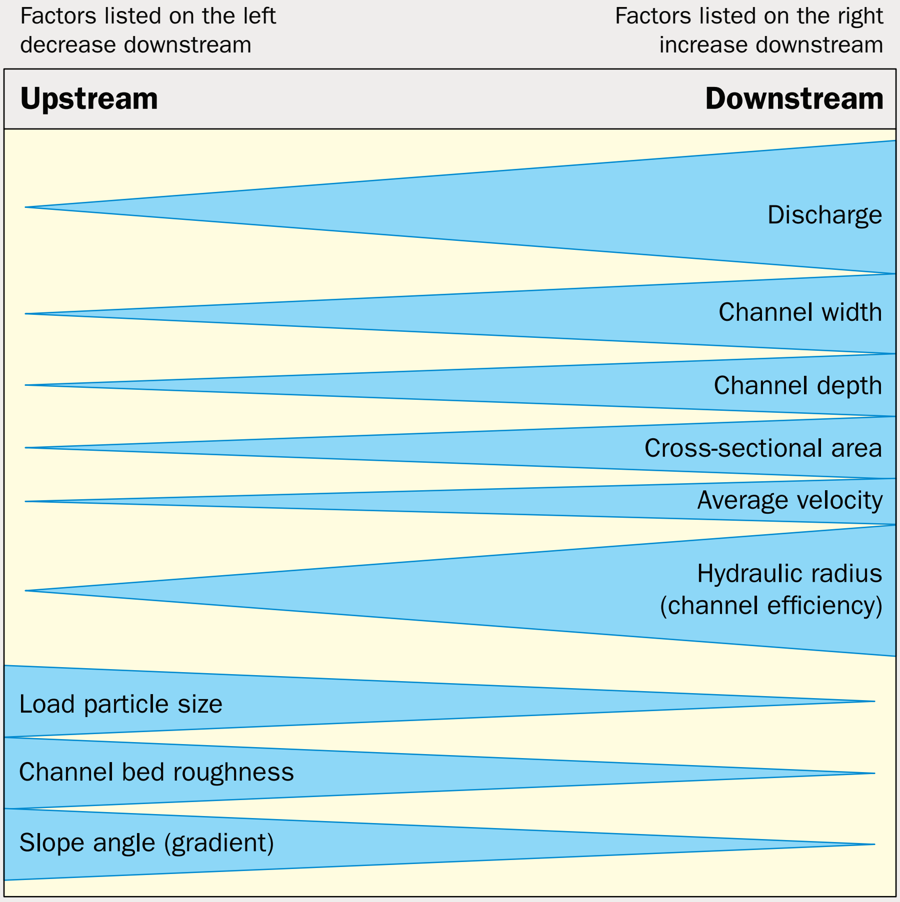

Figure 1 The Bradshaw model

Why do these changes occur?

The action of gravity on water at the Earth's surface causes it to move downhill following the contours of the landscape, from the steep slopes near the tops of hills to shallower slopes of lower ground. Therefore the steepness of the land (gradient) should be greater near the source of the river and become gentler as the river flows downstream. However, as water flows over soil and rock it also erodes both vertically and laterally. Over thousands and even millions of years the vertical erosion of a river produces a V-shaped valley cutting into the landscape. At the same time water in a river sloshes about from side to side and this erodes the banks of the river, widening it over time. As the river travels downhill, more water joins from tributaries and this lateral erosion widens the river further, increasing its cross-sectional area and allowing it to hold more water. More water increases the erosional power by increasing the velocity of the water, resulting in a wide and deep river mouth, where a large amount of water is discharged at the bottom end of the stream.

The River Tillingbourne – a case study

The purpose of this GeoActive unit is to use data collected by students to investigate the following question, concentrating on four parameters of the Bradshaw model:

To what extent do the characteristics of the River Tillingbourne agree with the Bradshaw model?

Quickfire facts about the River Tillingbourne (Figure 2):

- The river runs along the south side of the North Downs in Surrey. It has four tributaries.
- The source of the river is 294 metres above sea level at Leith Hill, the highest point in southeast England.
- The River is 19 km long and joins the River Wey as a tributary at 34 metres above sea level. The River Wey is itself a tributary of the River Thames, which discharges into the North Sea.

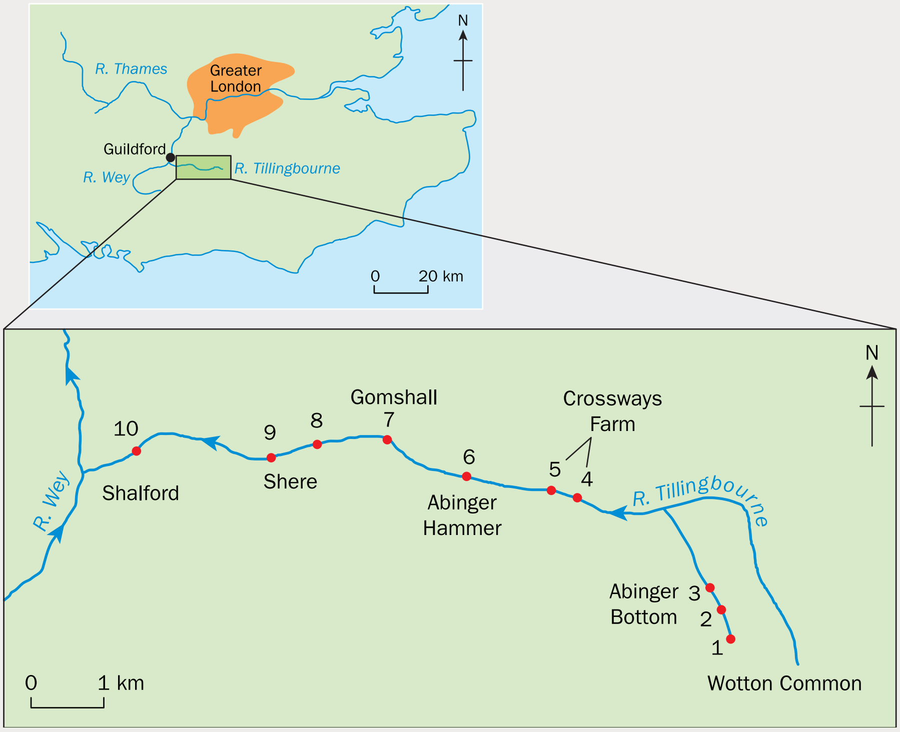

Figure 2 The course of the River Tillingbourne

Creating hypotheses

To investigate the question 'To what extent do the characteristics of the River Tillingbourne agree with the Bradshaw model', it is appropriate to identify some expected changes from the Bradshaw model that will take place as the river moves downstream. These changes can then be stated as a series of hypotheses which can be tested using data collected from the River Tillingbourne.

Hypotheses:

As the distance from the source increases, erosion will increase:

1 the width
2 the depth.

As the distance from the source increases the water will:

1 increase in velocity
2 increase in discharge.

Investigation method

To investigate the above hypotheses, measurements were taken in 10 locations along the river. Sites were selected based on landowner permission, safety considerations and ease of access to the river for students. At each site the dimensions of the river were collected using the same methods, as follows:

- **Measuring width** A tape measure is placed where the water meets the bank at one side of the river. It is then pulled tight across the water surface to the other bank, recording the distance in metres between the points.
- **Measuring depth** The width of the river is (in this case) divided into four equal sections. Facing upstream and starting at the left bank, a meter rule is placed into the water at the bank and the depth of the water was recorded in metres. The process is repeated at one-quarter of the way across, halfway, three-quarters and at the right-hand bank. The five depths are then averaged to give one overall reading.
- **Calculating cross-sectional area** This is the total area in which water flows. It is calculated by multiplying the width of the river by its average depth.
- **Measuring flow velocity** A meter ruler is placed on a bank of the river. A cork is dropped into the river upstream of the ruler. When the cork passes the start of the ruler a stopwatch is started. The watch is stopped when the cork passes the end of the ruler. The cork is then collected and the process repeated four more times. An average time of the five floats is calculated. Velocity, measured in metres per second, is then calculated by dividing the distance (1 metre) by the average time taken.
- **Calculating river discharge** The amount of water passing a point in the river is measured in cubic metres per second (m^3/sec). This is calculated by multiplying the cross-sectional area by velocity.
- **Measuring gradient** Two ranging poles are held at least 5 metres apart in the river with their bases just touching the water surface. A clinometer is placed against a fixed point on the upstream ranging pole and aimed at the same height on the downstream ranging pole. The angle of gradient can then be read off the clinometer.

> "Our hypotheses investigate width, depth, velocity and discharge."

Hypothesis testing

The impact of erosion

The first two hypotheses to be tested are those related to the process of erosion. If the River Tillingbourne follows the Bradshaw model, erosion vertically will increase the depth of the river downstream and lateral erosion will increase the width downstream.

Measurements of river width and depth for all 10 sites are displayed in Figure 3. The overall trend of Figure 3a shows that there is a general increase in width from around 0.5 metres near the source to around 7 metres at the 10th site,

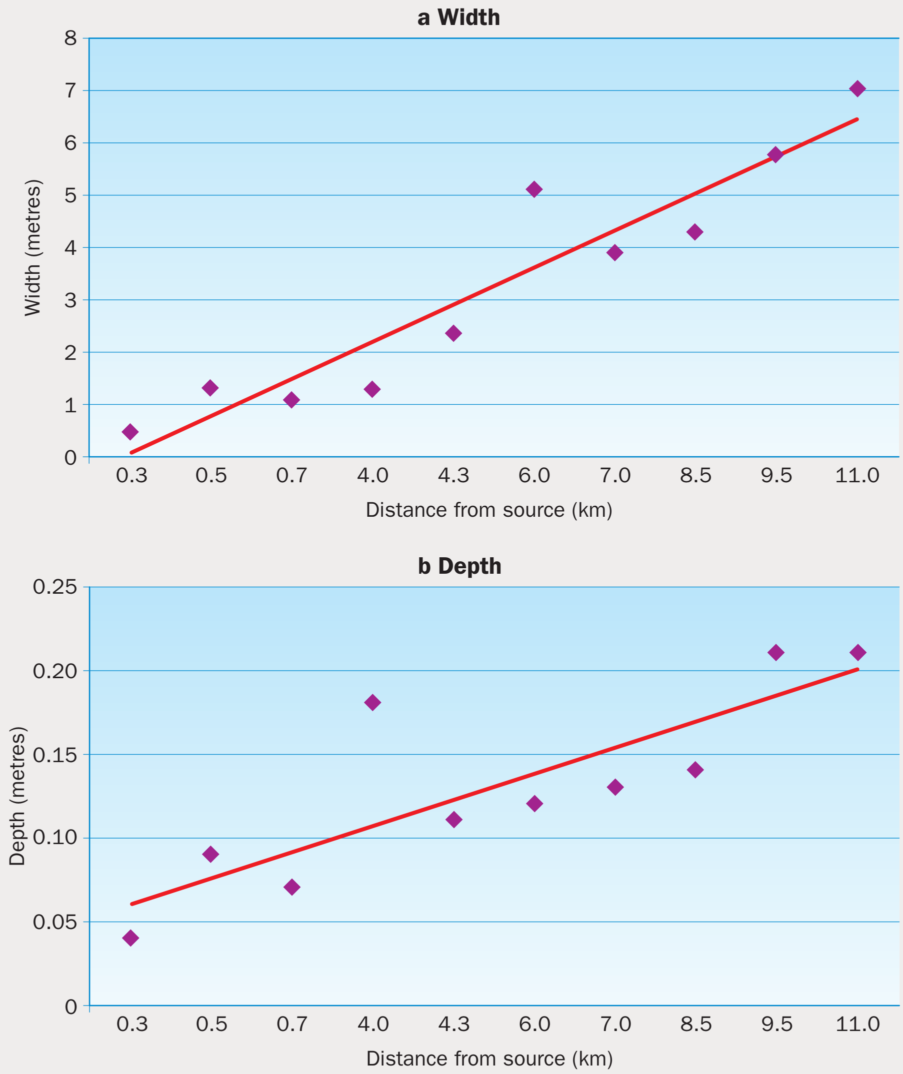

Figure 3 Measurements of width and depth

11 km downstream. This trend clearly proves the hypothesis of increased width. Figure 3b displays the average depth of the river at the same 10 sites and also shows that the depth of the river increases from 0.04 metres near the source to more than 0.2 metres after 11 km, also proving the hypothesis on depth. However, these graphs do not display a perfect relationship of change as shown in the Bradshaw model. Why is this?

One of the most obvious anomalies in width is at 6 km downstream where there is a noticeably greater width than might be expected based on the sites on either side (see Figure 3a). This does not fit the overall expected pattern. This site is in a village called Abinger Hammer and the river passes through the village green. Originally the river meandered across this green, taking up a lot of room. However, in order to allow the construction of a village cricket pitch, the river has been artificially straightened here by reinforcing the banks with concrete. The new river width is therefore not natural. It was made wider deliberately so that it would be less likely to cause a flood in the village.

Another anomaly can be seen in the depth data, Figure 3b. This time the unusual depth is at 4 km downstream at a location called Crossways Farm. Here the depth is 0.18 metres instead of an expected value closer to 0.1 metres. Although this is only around an 8 cm difference, it is around 80% greater than what should occur. If we take a look at Figure 4, this might give a clue to what is going on. At Crossways Farm the river has several quite pronounced meanders. As a river meanders, the water travels faster on the outside of the bends and erodes more deeply. This additional depth is then calculated as part of the average depth for the river channel and can make it appear deeper then might be expected.

Water movement

The second two hypotheses to be tested are those related to the velocity and amount of water, or discharge. If the River Tillingbourne follows the Bradshaw model it should become deeper and wider as it moves downstream so that it can hold more water. In addition, as more water is added, less of the water will be in contact with the bed and banks of the river, reducing friction. With reduced friction will come an increase in the velocity of the river.

Figure 4 Crossways Farm

Source: Photo by Robert Burn

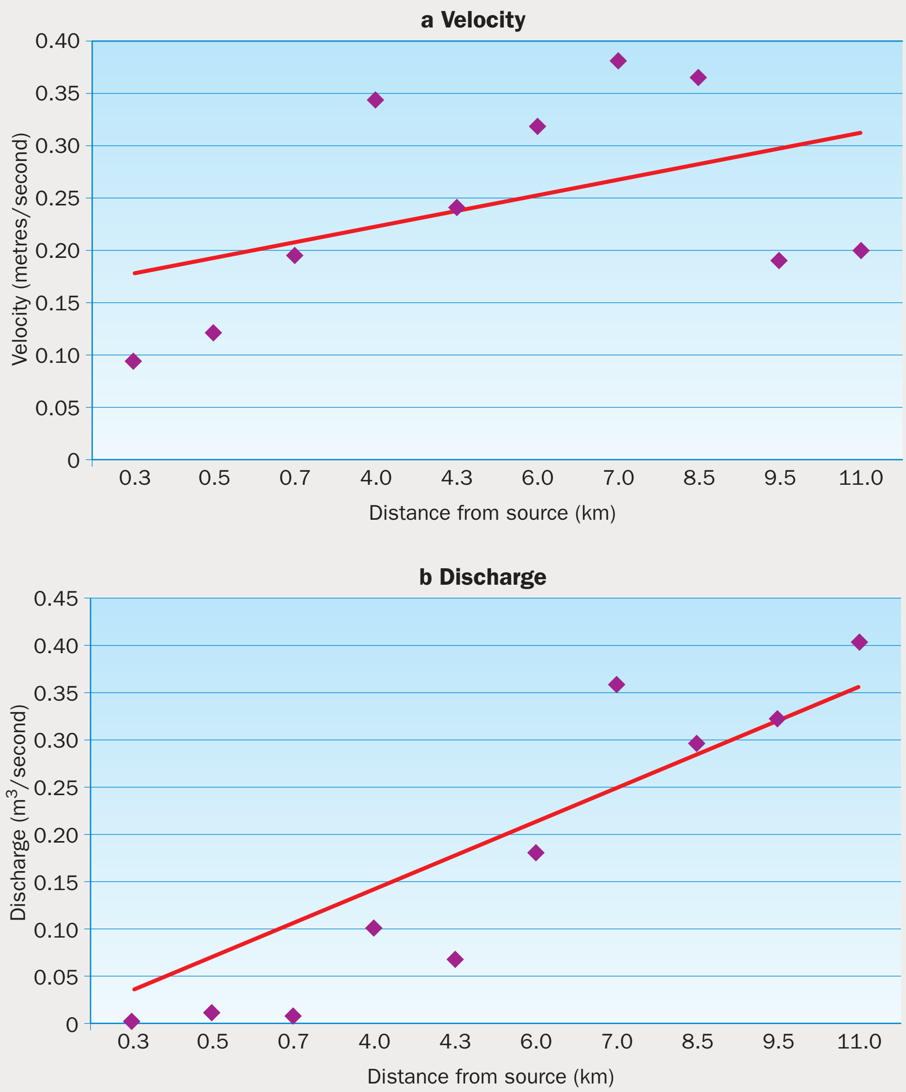

Figure 5 Measurements of velocity and discharge

Figure 5a shows the changes in velocity down the River Tillingbourne. Our hypothesis states that this should increase. As you can see, this is true for the first seven sites, so we can accept that the hypothesis for this section is correct. However, the last three sites show that the velocity then drops off. Why is this?

One possible reason why the velocity could decrease would be if water was being taken from the river. If this was true, more of the remaining water would have friction with the bed and banks, and it would slow down. However, when the widths (Figure 3a) and depths (Figure 3b) of the river are taken into account, there is no apparent drop in the cross-sectional area that would explain this.

In fact on testing the last hypothesis – that discharge should increase downstream – Figure 5b shows that this relationship is very strong and agrees with the hypothesis, giving no obvious reason for the drop in velocity over the last three sites.

An interesting observation of Figure 5a is that at site 7 (Gomshall) the drop in velocity occurs where a section of brick lining to the river banks comes to an end and the friction of banks becomes greater. This might also explain the slight decrease in discharge seen in the site after this in Figure 5b, but is not enough to explain the more substantial decline in velocity later on.

Conclusions

Conclusions can be drawn in answer to the question, 'To what extent do the characteristics of the River Tillingbourne agree with the Bradshaw model?'.

The data collected for the River Tillingbourne shows that we can accept all four of the hypotheses set, and that the River Tillingbourne generally gets wider, deeper, faster and has greater discharge as it flows downhill. The data also shows that this set of relationships is not perfect. Width, depth and discharge trends are fairly strong, with the odd, mostly explainable, anomalies. However, velocity data has a mysterious decline near the end of the river and this has not been adequately explained. Therefore, it appears that the River Tillingbourne strongly demonstrates the trends expected from the Bradshaw model, with the exception of velocity where the end of the river does not perform as expected.

Evaluation (or critique)

This investigation has concluded that the River Tillingbourne fits the Bradshaw model based on four aspects of the model. To test this relationship further it would be appropriate to compare other characteristics of the River Tillingbourne against the model, in an attempt to answer the question more fully. Collecting additional data and testing it using hypotheses in a similar way would allow this investigation to be more rigorous.

Activities

1 a To get a sense of the case study location, answer the following questions:

i How long is the River Tillingbourne?

ii Where does its source begin, and where does the river end?

iii What is the total drop in altitude of the river from its beginning to its end?

b Use Google Maps to locate the following sites:

i Crossways Farm in Dorking

ii Abinger Hammer

iii Gomshall.

At each site use Street View to get a sense of the river and its surroundings. Describe each location in writing.

2 Investigations involve a lot of forward planning before doing the fieldwork.

a What is the difference between a question and a hypothesis?

b Draw a series of annotated diagrams to show how data methods work for width, depth, velocity and gradient.

c Suggest how sources of error could creep into these methods and what could be done to reduce such errors.

d Write a risk assessment for students taking river measurements. Outline the hazards you might expect and how the level of risk might be reduced. Consider the nature of the sites you looked at in question 1b as part of this.

e Add a further risk assessment by researching Weils disease. What is it? How is it transmitted? How likely is it that students could contract it? What precautions should they take?

3 Use the data in Figure 6 to undertake the following activities on additional river parameters.

a Research the geographical term 'hydraulic radius'. What is this a measurement of?

b Use the Bradshaw model to write hypotheses for the following parameters on the River Tillingbourne:

- gradient
- cross-sectional area
- hydraulic radius.

c Plot appropriate graphs from the data in Figure 6.

d Write an analysis of your three graphs. Do they prove the hypotheses you set?

e Use your findings from question 3d, together with the findings in the case study, and write a new conclusion to the question: 'To what extent do the characteristics of the River Tillingbourne agree with the Bradshaw model?'

Extension

4 In a group, research and plan an investigation into a river near you. You could use the same parameters as use in this case study, or find others you might investigate such as bed load size and shape.

Site	Wetted perimeter (m)	Cross-sectional area (m^2)	Hydraulic. radius	Gradient
1	0.54	0.02	0.04	0.078
2	1.55	0.12	0.08	0.023
3	1.34	0.08	0.06	0.029
4	1.57	0.23	0.15	0.011
5	2.78	0.27	0.10	0.002
6	5.46	0.62	0.11	0.002
7	4.00	0.50	0.13	0.011
8	4.47	0.59	0.14	0.002
9	6.00	1.18	0.20	0.001
10	7.60	1.45	0.19	0.003

Figure 6 Data for a river

Learning checkpoint

- Rivers naturally follow a predictable set of changes in their characteristics as they move downstream.
- Creating hypotheses for these changes allows the use of river data to test them against the model.
- Sometimes rivers deviate from expected changes. This is often due to human intervention.

Glossary task

Write glossary definitions for these terms:

cross-sectional area **friction**
discharge **gradient**
hypotheses **tributary**
source **velocity**

Remember this case study

To help you understand the investigation process, use this case study and activities to help you write a structured plan on how to carry out a river investigation. Use the headings:

Aims **Methods**
Equipment **Safety**
Location **Sites**

Try to make your notes fit a single sheet of A4.