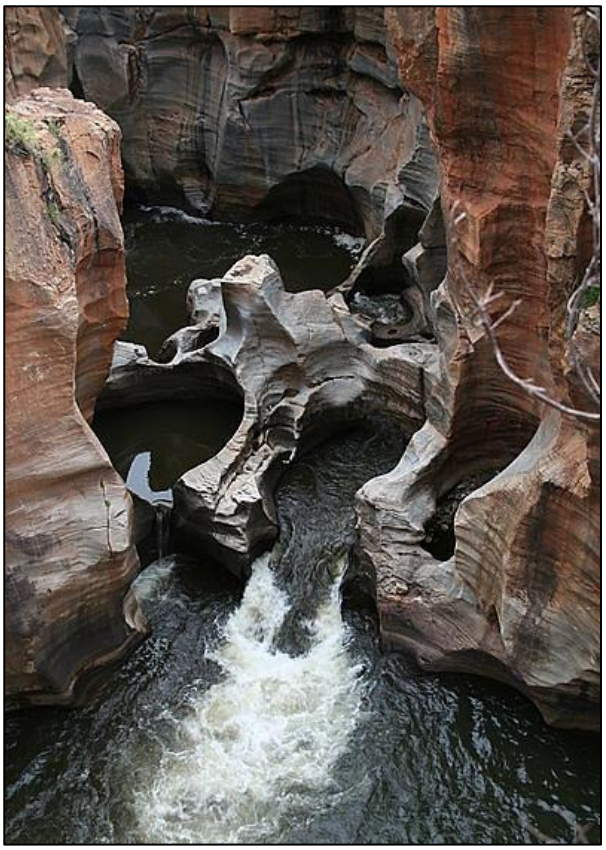
A bucket for a pothole: visualising past processes by calculation
Modelling river pothole-formation by calculation – thinking through the assumptions

Potholes like the ones in the photograph may have been formed by the grinding action of pebbles being swirled round by the fast-moving water. We can re-create these conditions by swirling pebbles in a bucket of water, using a 'spade'.



Swirling water in the Bourke's Luck Potholes, where the Treur River plunges into the Blyde River, Blyde River Canyon, South Africa.

Potholes formed during the Carboniferous period in Carboniferous Limestone, Traeth Bychan, Anglesey, UK. (*Maggie Williams*).

Fill a bucket around two thirds full of water and add a handful of pebbles. Then use your 'spade' to stir the water as smoothly as possible until the gravel is moving. If the water is too cloudy to see the movement, you should be able to hear the gravel moving instead.

'Stirring up' potholes in a bucket. (*Maggie Williams*).

Then ask the group how the speed of water flow needed to move the gravel can be calculated. The stirring speed can be worked out by measuring the radius of the stirring circle and then how many rotations of gravel-moving stirring are made in 30 seconds. The speed of flow is then found by:

$$\text{speed of flow in cm sec}^{-1} = \frac{2\pi \times \text{radius in cm} \times \text{no. of 'stirs'}}{\text{time in seconds}}$$

The calculated speed of flow needed to move gravel is the minimum speed necessary to form a pothole by grinding (abrading) gravel – but this calculation makes a number of assumptions which should be identified and considered during the demonstration, to provide a better understanding of the process.

The assumptions include:

- the flow of water is the same across the floor of the bucket – this is not the case, as the greatest speed of flow is near the outside, reducing to zero at the centre;
- the speed of water necessary to move gravel on the flat floor of a bucket is the same as is needed to entrain (move) the gravel in a gravel bed – this is not so, because the gravel bed is rough;
- the speed of flow near the gravel is the same as the water speed – it is actually lower because of the friction caused by the gravel;
- the speed of flow near the wall of the bucket is also reduced by friction;
- the bucket is the same shape as a pothole – buckets are usually tapered, which may not be the case for potholes.

You can check whether this field demonstration/ discussion gives appropriate results against the Hjulström–Sundborg curve, as discussed under 'Context' below.

The objective of this activity is to generate discussion and improved understanding of the processes likely to be involved in pothole-formation, rather than to approach a 'correct' answer.

The back up

Title: A bucket for a pothole: visualising past processes by calculation.

Subtitle: Modelling river pothole-formation by calculation – thinking through the assumptions.

Topic: How to simulate pothole formation in the field, involving calculation and the discussion of assumptions.

Age range of pupils: 14 years upwards

Time needed to complete activity: 15 minutes

Pupil learning outcomes: Pupils can:

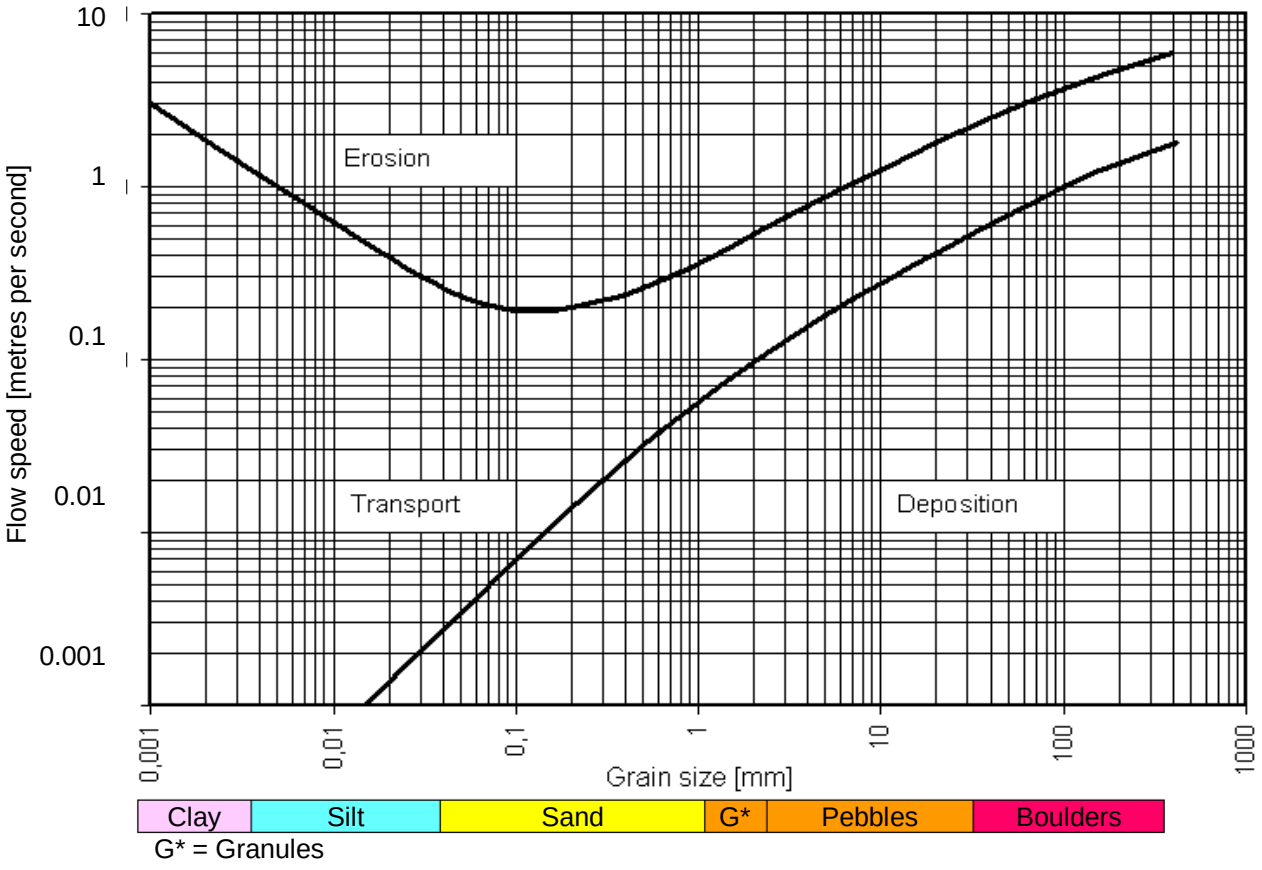
- describe how potholes can be formed by the abrasion of gravel carried by swirling water;
- calculate the circumference of a circle and speed of flow;
- discuss the range of assumptions made during the demonstration and calculation.

Context:
River potholes like the ones shown opposite are thought to have been formed by abrading gravel moved by eddies in the water as it flows over the bedrock. This activity seeks to mimic this mode of formation in order to provoke calculation and discussion around the processes involved.

Potholes in bedrock near the Aysgarth Upper Falls in Yorkshire, UK.

During field testing of this activity, gravel in the bucket was moved by circular stirring, with a stirring circle of radius 7cm and 55 stirs over 30 sec. The distance moved by the water is 2 x 3.14 (π) x 7 cm x 55 stirs = 44cm x 55 or 0.44m x 55 = 24.2m. The speed of flow was therefore 24m/30sec = 0.8msec^{-1}

You can check the flow speed at which gravel is eroded experimentally on the Hjulström–Sundborg diagram. This shows that flows of between around 0.8 to 3 msec^{-1} are necessary to move pebbles.



The Hjulström–Sundborg experimental diagram of flow speed against grain size.

Following up the activity:
Point out that the potholes commonly found in limestone associated with caves are formed by different processes mostly linked to chemical weathering, rather than by mechanical erosion. Study of this process could be linked to the 'Karstic scenery in 60 seconds' and 'Weathering limestone with my own breath' Earthlearningideas.

Underlying principles:
- River bed potholes are formed by the gravel abrasion of eddies of current.
- The processes can be simulated in a bucket, allowing the speed of flow necessary to move abrading gravel to be calculated.

Thinking skill development:
Arithmetical skills are required. Discussions of the assumptions involved in the simulation involve a range of evaluative skills.

Resource list:
- 10 litre (2 gallon) bucket
- a trowel or 'spade' as a stirrer
- water
- calculator

Useful links:
See a video of river pothole-formation at:
https://commons.wikimedia.org/w/index.php?title=File%3ANiebuchi_pothole_Toei_Aichi_Japan.ogg&uselang=en-gb

Source: Chris King of the Earthlearningidea Team, with key contributions by Martin Devon.