Engineers identify conditions that initiate erosion

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Wind, water, and waves erode billions of tons of soil from the earth's surface. As a result, many rivers are plagued with excessive amounts of suspended sediment. According to the U.S. Environmental Protection Agency, such eroded sediment is the largest nonpoint source pollution in the environment.

While the mechanism responsible for soil erosion may seem obvious –wind, water and wave forces breaking apart particles – in fact, the precise conditions or criterion that sets a particle free from its mates has not been identified. For 72 years, scientists and engineers have been working with a time-averaged force criterion, originally proposed by A. Shields, an American engineer, to describe threshold conditions for sediment to become mobile.

Now, a team of Virginia Tech College of Engineering faculty members and graduate students have demonstrated that sustained spikes in turbulence are responsible for dislodging particles, whether on land or in the water. They report their research results in the October 31 issue of *Science* in the article, "The Role of Impulse on the Initiation of Particle Movement Under Turbulent Flow Conditions."

Scientists and engineers have long suspected that turbulence, an ubiquitous feature of natural fluid flow phenomena, was part of the equation. Anyone who has flown has experienced turbulence. So a guess that turbulence is the culprit was still not sufficiently informative.

"There has been a need to develop a method that accounts for the role of turbulence on soil erosion in a quantitative way," said civil and environmental engineering Professor Panos Diplas, lead author on the research."If you measured the velocity of the air flowing across a fixed place in the middle of Virginia Tech's drill field, you would see that velocity fluctuates wildly," Diplas said.

"Wildly and randomly," said mechanical engineering Associate Professor Clint Dancey, co-author.

"When a weather report includes a high wind warning, it will go something like, '30 mph gusting to 70.' Yet the present system for determining erosion potential in a flow only measures a single, time-averaged value. "It does not account for the spikes or their duration," said Diplas.

Diplas, Dancey, and their students began to do experiments to determine the influence of the spikes. What they discovered is that not all spikes are created equal.

Using a metal ball slightly nested among Teflon balls, they introduced electromagnetic pulses of known magnitude and of different millisecond durations. The magnetic field simulated the drag of water in a river. "I had an 'aha moment' when I saw the video of that controlled experiment," said Dancey.

"We saw that, in addition to their amplitude, it was the duration of the 'gusts' that caused the metal ball to be dislodged or eroded from its resting pocket" said Diplas.

Using electromagnetic pulses, the team was able to establish a range of combinations of magnitude and duration that result in particle dislodgement. They call this product of magnitude and duration 'impulse'.

Next, the team moved their investigation to a two-foot-wide, 65-foot-long flume with actual water in the Baker Environmental Hydraulics Laboratory (www.hydraulicslab.cee.vt.edu) at Virginia Tech. The flume is used to simulated phenomena encountered in natural streams. A half-inch diameter ball was slightly nested on a bed of immobile 'pebbles'. Laser Doppler velocimetry (LDV) measured the instantaneous flow velocity of the water, which was allowed to move with the typical random turbulence of channel flows. Laser beams shining through the flume from outside recorded when the mobile grain moved. Thus the conditions of drag that caused erosion were captured. The results agreed with the findings of the electromagnetic study, the Science article reports.

"It is fundamental physics with broad applications to water or air flows," said Dancey. "The goal is to produce criteria that are more broadly applicable and have more predictive power."

And not only for the thresholds that result in soil erosion, but for the movement of contaminants. "A lot of particles have chemicals attached to them. At what point does pollution occur?" said Diplas. "That is, if pollutants are resting in a river bed, and there is a flood, at some point the turbulence is going to move the pollutants downstream. We need to know when this will happen!"

Another force capable of mobilizing particles is lift, the force that moves a buried particle out of its bed?. "We have employed a theoretical approach to explain what is happening when lift is the prevailing force experienced by a soil particle. The results in this case agree with those obtained from the electromagnet experiments when drag was the dominant force. Impulse, not just force, represents the more general criterion for identifying the critical conditions for particle dislodgement." Dancey said.

"We anticipate that this same mechanism will be responsible for particle dislodgement under the more general condition when both drag and lift forces contribute to particle movement," added Diplas.

Source: Virginia Tech