Researchers model behavior of stream flow

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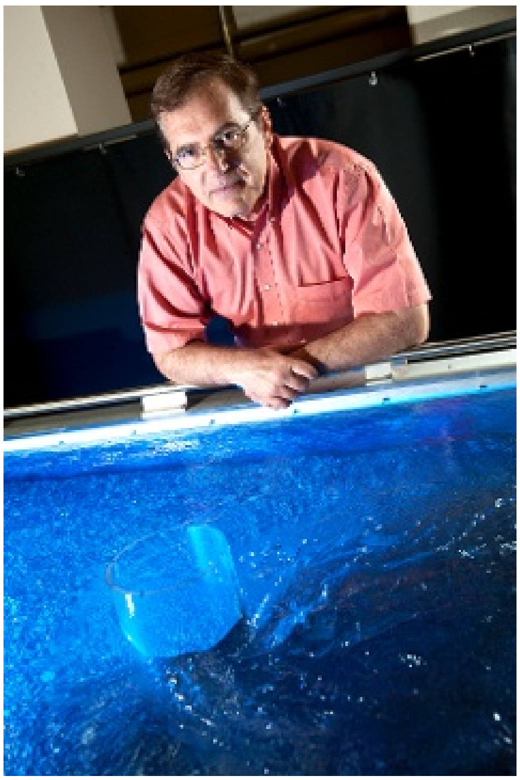

Panos Diplas.

Eighty billion metric tons is an unfathomable amount to the human brain. Yet that number is the estimation of the global amount of sediment eroded on a yearly basis over the continental surface of the earth. An estimated 20 billion of these metric tons end up in the ocean water via rivers.

The action of water and wind is responsible for this massive redistribution of materials, leading to significant water pollution and a variety of ecological problems.

"This redistribution of material over the surface of the earth affects most of its physical, chemical, and biological processes in ways that are not well understood and which are exceedingly difficult to comprehend," Panos Diplas, professor of civil and environmental engineering at Virginia Tech, said.

Farmers familiar with the flow of a small stream on their property can tell you tales of when that seemingly innocent body of water reacts to heavy downpours and becomes two, three, or even 10 times its normal size. It can move culverts, change course, and wash away low-lying areas adjacent to the stream, including gravel roads. Agricultural run-off is a huge problem in farming.

Diplas has spent part of his career studying river mechanics, improving the understanding of erosion processes and sediment transport. His multiple research findings over more than two decades earned him the 2012 Hans Albert Einstein Award, a lifetime achievement award. He was also a member of a team that received the 2012 Karl Emil Hilgard Hydraulic Prize for the best paper, and both awards came from the American Society of Civil Engineers.

At Virginia Tech, Diplas directs the Kelso Baker Hydraulics Laboratory, considered the best such facility in Virginia and the surrounding states. Civil engineering alumnus Kelso Baker of Sewickley, Pa., Class of 1951, provided the support to create this lab that enables researchers to study phenomena related to the movement of water, sediment, and pollutants through wetlands and waterways. The lab also provides the means for modeling the behavior of stream flow during floods, simulating ecological aspects of channel flows, and developing measures to control scour around bridge foundations and other structures.

The uniqueness of this university laboratory can provide Diplas and his colleagues a strong competitive advantage when applying for research project funding. For example, he currently is an investigator on several projects, including: two National Cooperative Highway Research program grants; two National Science Foundation awards; a $210,000 Defense University Research Instrumentation Program investigation; a $247,000 Army Research Office project; and a $258,000 Virginia Uranium Inc. study. These projects support work on bridge foundation scour, design of in-stream structures, movement of contaminants through a riverine system, role of turbulent flow on particle movement, and dam decommissioning.

Why so many different types of grants? As Diplas explained, the impact of flow in such areas as streams, rivers, floodplains, and in the vicinity of infrastructure, such as bridge crossings, has broad-reaching implications. It can "influence the hydrosphere, the pedosphere (the outer most layer of the earth composed of soil), the biosphere, and the atmosphere in profound ways," he said.

An overview of Diplas' expertise that garnered him the Einstein Award can be found in a book chapter he authored with Clinton Dancey, a faculty member and collaborator from the mechanical engineering department. The book, Coherent Flow Structures at the Earth's Surface, to be published in 2013, contains their chapter "Initiation of motion, sediment transport, and morphological feedbacks in rivers."

In it, they wrote, "Determining the minimum, or critical, force necessary to dislodge a particle out of its pocket, arguably constitutes one of the most fundamental and elementary problems in mechanics, regardless of the type of movement. When it comes to flow-induced forces, identifying this critical condition has confounded scientists and engineers for several hundred years.

"The main culprit for this problem is the fluctuating nature of the applied fluid forces, due to the turbulent nature of the flow, while the resistance to particle movement remains the same."

Diplas pointed to "coherent flow structure characteristics typically encountered in turbulent flows which dominate natural phenomena" and how they impact particle entrainment in water. He believes that particle dislodging in waterways is due to more than just force magnitude. The duration of the applied hydrodynamic forces is "relevant in predicting grain removal from the channel bed surface," he wrote in his book chapter.

Also, in the article that won him the Hilgard Prize, Diplas argued that "flow and turbulence are more influenced by the vegetation density" than by other factors.

Vegetation in aquatic environments "considerably alters the turbulent flow in streams, rivers, and floodplains. The additional drag exerted by plants largely influences ... the transport of sediments" and dissolved substances, Diplas said. This research was already substantiated.

Diplas' new contribution in this area of study is the result of his large-eddy simulation studies of turbulent flow. He was able to show through analysis that flow and turbulence are more influenced by vegetation density than by the cylinder-based diameter Reynolds number. In fluid mechanics the Reynolds number is used to characterize different flow regimes. When forces resistant to change dominate turbulent flow, it is likely to create eddies, vortices, and other flow instabilities.

Diplas' work in this area was supported by the National Science Foundation and eventually led to a publication in an issue of Science in 2008, "Analysis of impulse events associated to entrainment of coarse particles." Several more publications have followed the Science article, and several more are currently in press. The book chapter provides a summary of this work. A less technical discussion will appear in the 2014 issue of the McGraw-Hill Yearbook of Science & Technology.

"Your recent work published in *Science* is amongst the most important contributions to the sediment entrainment literature since the pioneering work of A.J. Grass in the early 1970s," wrote the editors of the book, Coherent Flow Structures at the Earth's Surface, in their letter inviting Diplas to contribute a book chapter. This book is part of a series published every 15 years summarizing the most important developments in river mechanics and related phenomena.

Provided by Virginia Tech

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