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HSL – A PREMIER LABORATORY FOR STATE, REGIONAL AND GLOBAL RESEARCH IN HYDRAULICS AND SEDIMENTATION ENGINEERING

BY THANOS PAPANICOLAOU, ACHILLEAS TSAKIRIS, CHRISTOPHER WILSON & BENJAMIN ABBAN

The recently established Hydraulics and Sedimentation Laboratory (HSL) at the University of Tennessee at Knoxville (hsl.engr.utk.edu) constitutes a premier facility for conducting innovative fundamental and applied research in environmental fluid mechanics, sedimentation engineering and watershed science. With state-of-the-art facilities and equipment, HSL aims to provide knowledge and address hydraulic engineering problems, while promoting at the same time the adoption of adaptive strategies towards addressing contemporary and future challenges at the state, regional, national and international levels.

Research with Depth and Breadth

The research conducted at HSL has three distinct but interconnected main thematic areas, namely:

1. Coarse-grained stream hydraulics, stream restoration, sediment transport processes
2. Cohesive soil/ sediment transport dynamics and source tracing
3. Ecological and biogeochemical processes in watershed and estuarine environments.

Hydraulics and Sediment Transport Processes in Coarse-grained Channels

The main thrust of the research activity at HSL is focused on the study of fundamental environmental fluid mechanics, hydraulics and sediment transport mechanics in coarse-grained streams. The improved fundamental knowledge gained from HSL research is oriented to the solution by a suite of practical engineering problems, thus assisting practicing engineers and other stakeholders effectively manage the environment in coarse-grained streams (Fig. 1). The spearhead of the research in this theme is focused on developing educated mountain stream restoration practices, with most prominent the understanding of the role of large boulders and similar structures (Fig. 2) in modifying the near-bed turbulent flows and controlling sediment transport patterns with implications to fish habitat, water quality and sediment management. Furthermore, our research in this

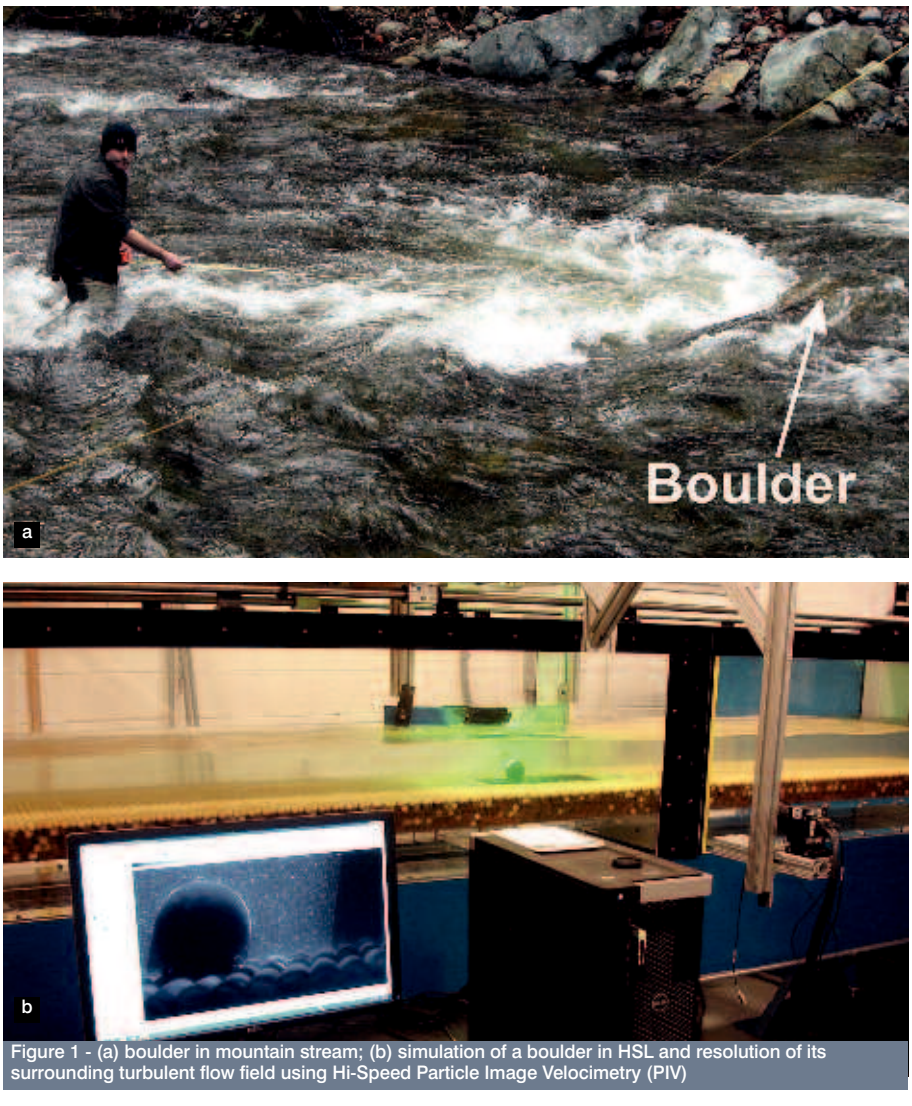


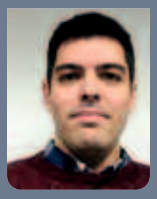
Figure 1 - (a) boulder in mountain stream; (b) simulation of a boulder in HSL and resolution of its surrounding turbulent flow field using Hi-Speed Particle Image Velocimetry (PIV)

theme goes hand-in-hand with the worldwide transition in analyzing bedload transport from an Eulerian to a Lagrangian perspective. Work in HSL concentrates on investigating coarse bed granular dynamics and grain-to-grain interactions, as well as diffusion processes. Along the same lines, research at HSL also focuses on scour around stream restoration and other hydraulic structures placed in coarse-grained streams, a topic which has received minimal attention in the past. For undertaking this research, HSL has two 10-m long, 0.60 m wide, water-recirculating flumes with adjustable slope up to 5%, one of which also allows sediment recirculation (Fig. 3). A plethora of measuring equipment is available for making high quality flow and sediment transport rate measurements, including a state-of-the-art Hi-Speed Particle Image Velocimetry (PIV) system, a 2D Laser Doppler Velocimeter (LDV) system, several 3D Acoustic Doppler Velocimeters (ADV), geophones, micro-pressure transducers, Radio Frequency IDentification (RFID) sediment particle tracking equipment and, sonar bathymetric devices among others. The HSL also offers space, electromechanical infrastructure and unique expertise for constructing physical models.

Cohesive Sediment Transport and Dynamics

A key topic of HSL research is the erosion of cohesive stream banks (Fig. 2), a process

Thanos Papanicolaou, **Professor and Henry Goodrich Chair of Excellence in Civil and Environmental Engineering at the University of Tennessee, Knoxville is the Director of the Hydraulics and Sedimentation Laboratory. Since receiving his M.Sc. and Ph.D. degrees in Civil and Environmental Engineering from Virginia Tech, he has been actively involved in experimental fundamental and applied research in environmental fluid and sediment transport mechanics, as well as in numerical modeling of riverine and watershed transport processes. Having authored over 100 articles in 42 different discipline journals, he is currently the Director of the Tennessee Water Resources Center, as well as the chief Editor of the Journal of Hydraulic Engineering, ASCE.**



Achilleas Tsakiris **was appointed as the manager of the Hydraulics and Sedimentation Laboratory after completing his M.Sc. and Ph.D. studies at the University of Iowa in 2014. His research interests include fundamental hydraulics and interaction between sediment, structures and flow turbulence, modeling as well as fluidization of cohesive sediment. He is also actively involved in sensor development for surrogate bedload transport and bridge pier scour. .monitoring.**

Christopher Wilson **is the field coordinator for HSL. He holds a B.S. in Biology/Ecology from Rhodes College and a Ph.D. in Geological Sciences. Additionally, he has worked at the USDA-ARS National Sedimentation Lab before joining the team. His research interests include examining the movement of water, soil, and carbon through the Earth's critical zone through source tracking of radionuclides and other hydropedological properties, as well as studies related to bank erosion, soil health, and evaluating conservation practices.**

Benjamin Abban **is a researcher at HSL. He holds an M.Sc degree in Civil Engineering from the University of Cape Town. His research interests include upland erosion processes, watershed dynamics and scaling laws, knickpoint development and migration, and local scour around bridge piers and abutments. He is also interested in computational modeling of river networks, as well as the use of various sensor technologies such as Radio Frequency IDs and laser scanning systems for monitoring land surfaces changes and sediment fluxes.**

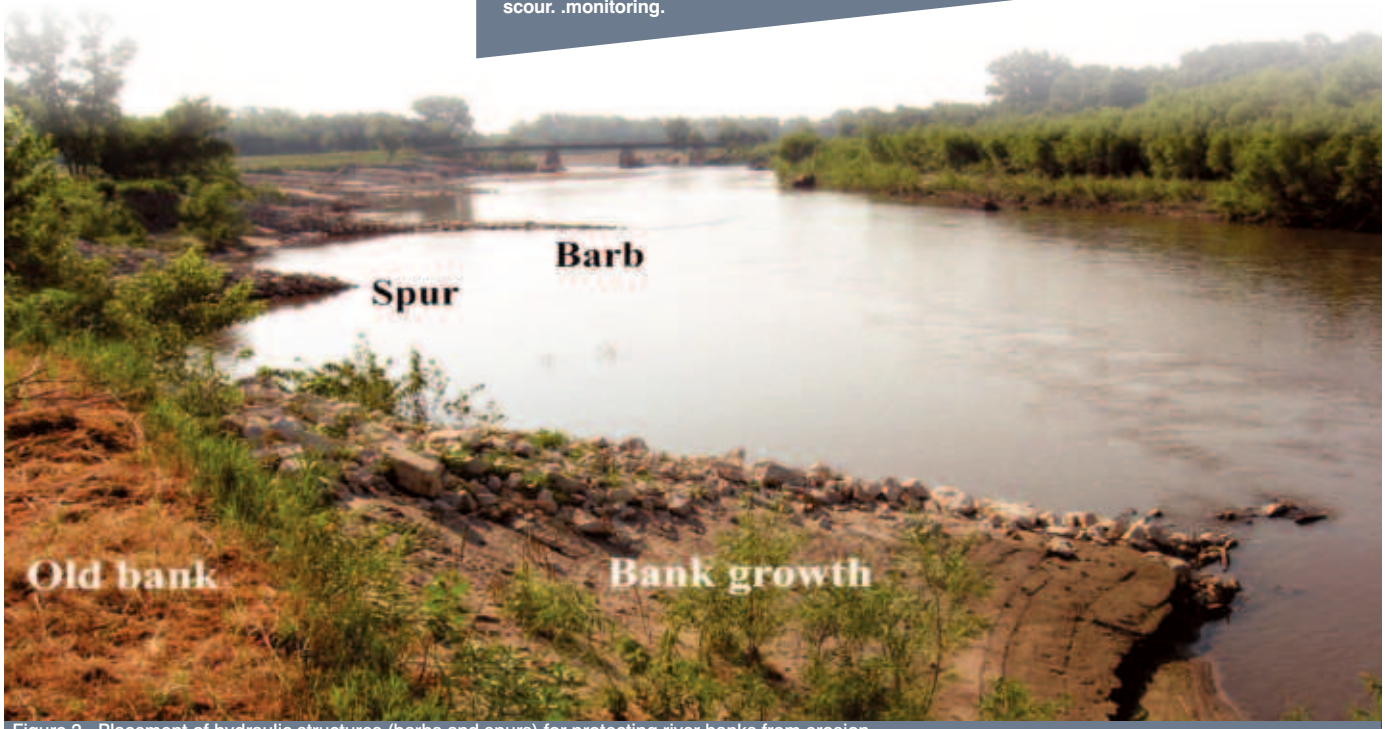


Figure 2 - Placement of hydraulic structures (barbs and spurs) for protecting river banks from erosion and preventing loss of agricultural land

encountered world wide with important implications on lateral stream migration, safety of bridge, highway and other infrastructure, water quality and loss of arable land. Research at HSL concentrates on isolating the different mechanisms of bank erosion and quantifying the erosional strength of different soils, as well as the effects of soil properties, temperature changes and vegetation. In doing so, we seek to develop predictive relationships for bank erosional strength suitable for use by practicing engineers and planners. Instrumental to the study of cohesive bank erosion at HSL are a prototype conduit (Fig. 3) and a mini-open channel mobile flume which has been designed in-house specifically for estimating the critical erosional strength of bank materials in the laboratory or in situ. Within the framework of cohesive sediment transport, work at HSL also focuses on the phenomenon of fluidization and the resulting piping within soils that arises from pore water pressure variations in the soil. Fluidization is applications in fluid mud management in harbors, estuarine dynamics, dam seepage and gas (methane or gas hydrates) upwelling in lakes and dam reservoirs. HSL offers the capability and technical expertise for replicating the fluidization and piping phenomena in the controlled laboratory environment thus allowing isolation of the underlying physical mechanisms. A wide array of measurement equipment, such as miniature pressure transducers, high-definition imaging and image analysis and a microscope lens assist in making detailed measurements of pore water pressure and observations of the soil structure.

Source Tracing and Nutrient Cycling

Research at HSL is also focused on understanding the source and transport of sediment and nutrients (e.g., nitrogen and phosphorus)

Research at HSL focused on understanding the source and transport of sediment and nutrients in intensively managed landscapes

in urban and agricultural watersheds and particularly in intensively managed landscapes. Through this understanding, we sought to inform the decisions of land managers, farmers and other land stakeholders towards a more sustainable agriculture. For this type of research, HSL has a mobile rainfall simulator unit capable of performing in-situ experiments (Fig. 4) simulating natural storms for studying the movement of soil at the plot or watershed scales. The mobile unit is complemented with an array of equipment for measuring suspended sediment concentration, infiltration, bed microtopography, moisture, erosion depths, pressure and temperature. Furthermore, HSL is equipped with a gamma sourcing facility that allows tracing sediment with radioisotopes including 210Pb, 7Be, and 137Cs. Under the lead of Prof. Papanicolaou, Dr. C.G. Wilson coordinates the field experimental campaigns and the radionuclide tracing, which are complemented with numerical modeling supervised by B. Abban. This research is enhanced with the study of carbon cycling in the landscapes for gaining insight into the fertility of soil.

New Initiatives and Worldwide Networking

Constantly adjusting and adapting to contemporary challenges, HSL seeks to expand its research capabilities in parallel with the three main research thematic areas. As part of this effort, HSL is applying knowledge gained by research on Critical Zone dynamics for studying sustainable ways of producing food, water and energy. Along the same lines, HSL plays a key role worldwide in developing new generation of sensing technologies for developing "smart" infrastructure and for supplying newly developed numerical models with accurate and actual data. A key step in this direction is the development of an automated, remotely operating system based on RFID technology for automated monitoring of scour around bridge piers and other hydraulic structures.

In these new initiatives, HSL is partnering and collaborating with many institutions in the public and private sectors nationally and internationally. HSL is building connections with other laboratories in Australia, New Zealand, India and Europe, with the United States Bureau of Reclamation (USBR) and the United States Department of Agriculture – Agricultural Research Service (USDA-ARS) laboratories, and with the United States Army Corps of Engineers (USACE) and the United States Geological Survey (USGS) southeastern region to address significant environmental problems such as the hypoxia and the BP Horizon disaster problems in the Gulf of Mexico. In addition HSL is developing a partnership with the Tennessee Valley Authority on water and dam operations as well as with ORNL on biogeochemical cycles and hydropower energy. ■

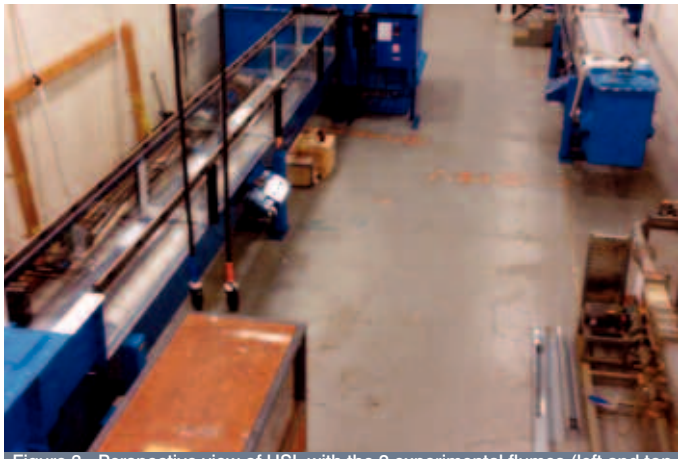


Figure 3 - Perspective view of HSL with the 2 experimental flumes (left and top right) and the conduit erosion flume (bottom right)

Figure 4 - Rainfall simulator unit deployed in situ for studying upland erosion in an agricultural field