Date of Submission	22 April 2026

IPL Project 256 Annual Report Form

Period of activity under report
from 1 January 2025 to 31 December 2025

1. **Project Number and Title: IPL-256, Investigation of landslide initiation caused by rainfall infiltration using small-scale physical and numerical modeling (ILIRIM)**

2. **Main Project Fields**

   Select the suitable topics. If no suitable one, you may add new field.

   (1) Technology Development

   A. Monitoring and Early Warning, B. Hazard Mapping, Vulnerability and Risk Assessment

   (2) Targeted Landslides: Mechanisms and Impacts

   A. Catastrophic Landslides, B. Landslides Threatening Heritage Sites

   (3) Capacity Building

   A. Enhancing Human and Institutional Capacities

   B. Collating and Disseminating Information/ Knowledge

   (4) Mitigation, Preparedness and Recovery

   A. Preparedness, B. Mitigation, C. Recovery

   (5) Landslide Modeling

   A. Physical modeling, **B. Numerical modeling**

3. **Name of Project Leader: Assoc. Prof. Josip Peranić, PhD CE**

   Affiliation: University of Rijeka, Faculty of Civil Engineerin (Croatia)

   Telephone: +385 51 265 936

   Email: josip.peranic@gradri.uniri.hr

   Core members of the Project:

   Željko Arbanas/ University of Rijeka, Faculty of Civil Engineering, ICL President, Professor Emeritus; zeljko.arbanas@gradri.uniri.hr

   Vedran Jagodnik/ University of Rijeka, Faculty of Civil Engineering, Head of Geotechnical Laboratory, Associate Professor; vedran.jagodnik@gradri.uniri.hr

   Martina Vivoda Prodan/ University of Rijeka, Faculty of Civil Engineering, Associate Professor; martina.vivoda@gradri.uniri.hr

   Josip Zorčić/ University of Rijeka, Faculty of Civil Engineering, Research Assistant and PhD Candidate; jzorcic@uniri.hr

4. **Objectives** (5 lines maximum): Investigate the hydro-mechanical response of soils and slope models exposed to simulated rainfall using a newly developed platform for testing downscaled slope models under 1*g* conditions; Use of the experimental data together with numerical modeling to investigate the role of rainfall characteristics, hydro-mechanical soil properties, geometric and boundary conditions in landslide initiation by rainfall; Investigate the applicability of the adopted research methodology in defining rainfall thresholds.

5. **Study Area**: The research activities will be carried out in the Geotechnical laboratory of the Faculty of Civil Engineering, University of Rijeka, Croatia.

6. **Project Duration**: 4 years (research remains actively being conducted and thus, if possible, would probably be further extended!)

7. **Report**

1) Progress in the project: During the fourth year of the project, extensive laboratory testing was carried out to achieve advanced hydro-mechanical characterization of soils used in physical slope models, as envisaged in the project proposal. These tests provided essential material properties for interpreting experimental results and conducting advanced numerical analyses. The testing program included: (i) classification and basic soil index properties; (ii) advanced hydraulic characterization, including determination of the Soil Water Retention Curve (SWRC) and Hydraulic Conductivity Function (HCF); and (iii) determination of (un)saturated shear strength properties. In parallel, additional numerical modelling activities were conducted, both at the host institution and in collaboration with Iowa State University, involving Prof. Beena Ajmera and her PhD candidate Rupsa Roy. These efforts focused on evaluating the predictive capabilities of hydromechanical slope response models under rainfall loading. The results have been widely disseminated at international conferences, and one related research paper is currently under review in an international journal. Within the project framework, one Master's thesis ("Determination of the Unsaturated Shear Strength of Sandy Soil") was successfully defended in 2025, while two additional students are currently engaged in experimental research related to physical modelling. The project also supported international mobility. Data from earlier project phases were utilized by visiting student Adelie Leonard from Institut Polytechnique de Grenoble. Her research internship at the University of Rijeka (June–September 2025) resulted in findings presented at the 3rd International Workshop on Soil-Vegetation-Atmosphere Interaction (November 2025, Bari). The expertise and results generated within this project significantly contributed to securing competitive funding for two new projects: (i) From Laboratory to Field: A New Soil Characterization Approach for Landslide Modelling (University of Rijeka; €40,000; 2025–2029), and (ii) Advanced Landslide Modelling through Field-Monitoring-Based Soil

Characterization (Croatian Science Foundation; €250,000; 2026–2031). The latter will enable the establishment of a new research group and recruitment of doctoral and postdoctoral researchers. These initiatives will further strengthen international collaboration and promote researcher mobility ("brain circulation") among partner institutions, including the University of Salerno, Iowa State University, Norwegian Geotechnical Institute, University of Udine, and University of Ljubljana. Overall, the project has significantly advanced research capacity, visibility, and the foundation for future competitive international funding.

2) Planned future activities or statement of completion of the Project: In the coming year, further modifications to the experimental setup will be carried out. Ongoing upgrades to the rainfall simulator unit include the implementation of newly acquired nozzles designed to enable the application of very low rainfall intensities. This will allow completion of data in the dry range of the Soil Water Retention Curve (SWRC) and facilitate testing of fine-grained soils, while also addressing additional issues identified during previous project activities, outlined through recent publications. Newly designed experiments will be conducted to establish a novel approach for the hydraulic characterization of unsaturated soils over a wide range of soil suctions, including values beyond the measurement limits of conventional tensiometers. These experiments will form the basis for the development of innovative experimental procedures for advanced soil characterization, with particular emphasis on determining the unsaturated hydraulic conductivity function—one of the most challenging soil properties to measure directly, yet a key factor controlling the hydraulic response of slopes under rainfall infiltration. In parallel, dissemination of results and collaboration with project partners will continue, with a particular focus on submitting research outputs to selected ICL publications during 2026.

3) Beneficiaries of Project for Science, Education and/or Society: From a scientific perspective, the project generates new knowledge on the hydro-mechanical behaviour of soils and slopes under varying rainfall and boundary conditions. The integration of laboratory testing, physical modelling, and numerical analyses improves understanding of rainfall infiltration, slope stability, and the behaviour of saturated and unsaturated soils. Observations of pore water pressure, soil moisture, hydraulic hysteresis, and shear strength under partially saturated conditions address key challenges in rainfall-induced landslides. The development of improved methodologies for determining unsaturated soil properties further strengthens the project's scientific impact.

   The results are directly relevant for researchers and practitioners in geotechnical engineering and natural hazard assessment, supporting more reliable prediction of slope responses and improved landslide risk mitigation, with clear societal benefits for affected communities. Research outcomes are disseminated through conferences and publications, including those of the International Consortium on Landslides, enhancing visibility and collaboration. The project also has a strong educational role, involving students at all levels in research activities and thesis work, while promoting international mobility and "brain circulation." Overall, it contributes to

scientific advancement, capacity building, and increased societal resilience to natural hazards.

4) Results: The results of the project have been disseminated through conference contributions, invited lectures, and journal publications (published, accepted, or under review), as outlined below:

- Peranić, J., Leonard, A., Kocijančić, L., Arbanas, Ž. (2025) "Investigating the effect of rainfall patterns on slope stability through physical and numerical modelling." *In: Boldrin, D., Cecconi, M., Cotecchia, F., Leung, A., Pedone, G., Perrini, P., Romero, E., Tagarelli, V., Zdravković, L. (eds), Proceedings of the 3rd International Workshop on Soil-Vegetation-Atmosphere Interaction (RootS25)*. ISSN: 3107-300X. https://doi.org/10.53243/RootS2025-55

- Roy, R., Ajmera, B., Peranić, J., and Arbanas, Ž. (Under Review) "Forward Prediction of Slopes Subjected to Rainfall", *Landslides.*

- Roy, R., Ajmera, B., Peranić, J., and Arbanas, Ž., (Under Review) "Blind Prediction of Hydraulic and Mechanical Response of Rainfall-Induced Slope Failures", *Proceedings of World Landslide Forum 7, India*.

- Roy, R., Ajmera, B., Arbanas, Ž., and Peranić, J., (In Press) "Type B1 Predictions of Slope Performance During Rainfall Using Numerical Analysis," *Proceedings of 21st International Conference on Soil Mechanics and Geotechnical Engineering (ICSMGE 2026)*.

- Peranić,J. (2025). Uloga mehanike nesaturiranog tla u istraživanju klizišta uzrokovanih infiltracijom kiše *(The Role of Unsaturated Soil Mechanics in the Study of Rainfall-Induced Landslides)*. Invited lecture at the "Zajednički temelji 2025" conference (in Croatian).

- Roy, R., Ajmera, B., Peranić, J., and Arbanas, Ž., "Blind Prediction of Hydraulic and Mechanical Response of Rainfall-Induced Slope Failures," ASCE Geotechnical Conference Poster Competition, Ames, IA. (Secured 3rd Place in Poster Competition, March 2026).

- Roy, R., Ajmera, B., Peranić, J., and Arbanas, Ž., "Predicting Rainfall-Induced Slope Behavior with Limited Input Parameters," 14th Annual CCEE Student Research Showcase and Poster Competition, Iowa State University, Ames, IA. (April 2026).

- Roy, R., Ajmera, B., Arbanas, Ž., & Peranić, J., "Rainfall-Induced Slope Performance: A Forward Prediction Approach," Geo-Poster Competition (Top 8 Finalist) at Geo-Congress 2026, Salt Lake City, UT, USA. (March 2026).

- Final and Master's Thesis Conducted as a part of the Project:
  - Dora Štiberc: Determination of the Unsaturated Shear Strength of Sandy Soil. Master's thesis defended in July 2025 (Supervisor: Assoc. Prof. Josip Peranić)
  - Luka Mataija: Response of Slope Models under Low Rainfall Conditions - Modifications to

the Rainfall Simulator. Master's thesis (Supervisor: Assoc. Prof. Josip Peranić; in prep)

- Filip Kranjčec: Calibration of soil moisture sensors for monitoring the hydraulic response of a slope. Final thesis (Supervisor: Assoc. Prof. Josip Peranić; in prep)