Date of Submission	30th October 2020

IPL Project (IPL - 220) Annual Report Form 2020

1 January 2019 to 31 December 2019

1. Project Number (approved year) and Title,

   IPL-220 (2017) Kostanjek landslide monitoring project (Zagreb, Croatia)

2. Main Project Fields

   Technology Development (Monitoring and Early Warning), Preparedness, Capacity Building (Enhancing Human and Institutional Capacities, Collating and Disseminating Information/ Knowledge)

3. Name of Project leader

   Martin Krkač
   Affiliation: Assistant Professor
   University of Zagreb, Faculty of Mining, Geology and Petroleum Engineering
   Contact: Pierottijeva 6, HR-10000 Zagreb, Croatia, mkrkac@rgn.hr

   Core members of the Project: Names/Affiliations:

   - Snježana Mihalić Arbanas, Full Professor, University of Zagreb, Faculty of Mining, Geology and Petroleum Engineering
   - Sanja Bernat Gazibara, Research Assistant, University of Zagreb, Faculty of Mining, Geology and Petroleum Engineering
   - Marin Sečanj, Assistant, University of Zagreb, Faculty of Mining, Geology and Petroleum Engineering
   - Željko Arbanas, Full Professor, University of Rijeka, Faculty of Civil Engineering

4. Objectives: (5 lines maximum)

   The project aim is to develop a procedure for prediction of the Kostanjek landslide movement in order to mitigate the landslide risks. Establishment of the procedure for prediction of the landslide movement consists of two objectives. First objective is development of the phenomenological (statistical) model for prediction of landslide movement and the second objective is automatization of the landslide prediction process through the development of customized software.

5. Study Area: (2 lines maximum)

   Kostanjek landslide, located in the urbanized area of the City of Zagreb, Croatia. Kostanjek landslide is the biggest landside in Republic of Croatia.

6. Project Duration (1 line maximum)

   3 years

7. Report

1) Progress in the project: (30 lines maximum)

   During the 2019, two phases of the project were carried out, the fourth and the fifth phase. The fourth phase is related to testing of prediction models. Tested models are models for prediction of groundwater levels, models for prediction of groundwater level change rates and the models for prediction of landslide movement (velocity). The input data for the prediction of groundwater level and change rate were various parameters such as different antecedent and modified precipitations, while for landslide movement prediction parameters were groundwater level and different period groundwater level changes. All models were tested with two statistical techniques, Random Forests (RF) and Multiple Linear Regression (MLR). The tested results were compared with the k-fold cross-validation, a statistical method for evaluating and comparing learning algorithms. According to k-fold cross-validation, the RF and MLR models for the indirect prediction of GWL show smaller average root mean square error (RMSE) than that of the models for direct prediction. The RF models for prediction of GWL changes and landslide velocity generally show smaller RMSE than MLR models. The fifth phase of the project is development of customized software which includes visualization of monitoring data in real time, calculation of prediction parameters and prediction of landside movement with selected statistical model. Currently, selection of necessary and representative parameters, as well as visual framework of the application is underway. After selection of visual framework and representative parameters, follows a process of the application/software development for prediction of landslide movement, updated on a daily basis, as new data are receiving from the monitoring site, as well as definition of a threshold values.

2) Planned future activities or Statement of completion of the Project (15 lines maximum)

   The future activities, which follow the selection of the visual framework for the application, encompass the development of functional software for prediction of movement. After finishing the application/software, it is necessary to test its functionality and to prepare procedures in case of different scenarios related to threat posed by landslide. Procedures will prepare the scientists involved in project in cooperation with those responsible for managing the risks posed by landslides in City of Zagreb. The next step should be application and adjustment of the developed

software for other landslides in City of Zagreb and in Croatia.

3) Beneficiaries of Project for Science, Education and/or Society (15 lines maximum)

The main beneficiary will be emergency management offices and the civil protection of the City of Zagreb, as well as residents endangered by the Kostanjek landslide. The research promote innovation in the field of landslide monitoring and prediction. The beneficiaries of the research are also professionals and scientists involved in geological and geotechnical engineering who are in charge of landslide research and education.

4) Results: (15 line maximum, e.g. publications)

Current results of the project provide new knowledge about the Kostanjek landside behavior, its movement characteristics and its relation to the triggers. Current results of also provide information about quality of different models for the prediction purposes and their usefulness in the landslide management.

Krkač M, Bernat Gazibara S, Arbanas Ž, Sečanj M, Mihalić Arbanas S. (2020): A comparative study of random forests and multiple linear regression in the prediction of landslide velocity. Landslides, 1–17. https://doi.org/10.1007/s10346-020-01476-6

Krkač M, Bernat Gazibara S, Sečanj M, Arbanas Ž, Mihalić Arbanas S. (2019): Continuous monitoring of the Kostanjek landslide. In: Uljarević M., Zekan S., Salković S., Ibrahimović Dž. (eds): Proceedings of the 4th Regional Symposium on Landslides in the Adriatic-Balkan Region. Geotechnical Society of Bosnia and Herzegovina, Sarajevo, 43-48.

Note:

1) If you will change items 1)-6) from the proposal, please write the revised content in Red.
2) Please fill and submit this form by 30 October 2020 to ICL Network <icl-network@iclhq.org>