

Geoscientists without borders – geosciences in solving humanitarian problems

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After heavy rainfall in the Balkan region (May 2014) that caused a lot of damage from floods in Bosnia and Serbia, the Association of Geophysicists and Environmentalists of Serbia (AGES) launched, with the support of SEG's (Society of Exploration Geophysicists) program Geologists Without Borders and the local community, a two-years long humanitarian project called The Assessment of infrastructure caused by floods in Bosnia and Herzegovina and Serbia. Geoscientists without Borders is a new program by the SEG Foundation sponsoring the application of geophysics and geosciences in solving humanitarian problems worldwide. This program aims to connect universities and experts from the local community, which were hit by a natural disaster.

The aim of the project is to combine several geophysical methods in order to establish the most efficient methodology which can define and remediate the existing landslides and prevent the emergence of new ones. Combining several geophysical methods, such as seismic (reflective, refractive, MASW), electric, EM and satellite methods, the obtained results will be presented to the relevant local authorities. Based on these results, mitigation measures of the investigated landslides will be proposed. Through multidisciplinary partnership and

cooperation of AGES and the local community with experts from the world famous institutions dealing with engineering and geosciences, global geophysical community will be significantly strengthened. Also, training students in the application of geophysical methods is another aspect of the project. Students of undergraduate and graduate studies involved in the field work, as well as data processing and interpretation, will learn the practical aspects and the importance of geophysics. These students will be the next generation of geophysicists who will deal with predicting and preventing similar disasters in locations prone to landslides across the region.

Keywords: Landslides, Geoscientists without Borders, Serbia, BiH.

Introduction

In May 2014, a heavy rainfall caused an extensive disaster in the Balkan region (Figure 1). The damage was particularly severe in the catchment area of the River Sava. According to the European Bank for Reconstruction and Development (EBRD), the damage was estimated at around 1.5 to 2 billion euros in Serbia, and about 1.3 billion Euros in Bosnia and



Figure 1. Satellite image of the rain cloud covering Europe on 13 May 2014.

Herzegovina (BiH), (SBS, 2015). More than 1 50.000 people were evacuated and the total number of affected people reached 1.6 million. Houses were destroyed or partially damaged by floods due to the overflowing rivers and failed river banks in the plain areas, and by landslides in the hillsides. The number of landslides counted over 2000. This highlighted the danger of living in landslide prone areas, and the need for assessing the landslide potential.

Among the wide range of aids from all over the world, The Society of Exploration Geophysicists (SEG) sponsored a Geoscientists without Borders (GwB) project initiated by The Association of Geoscientists and Environmentalists of Serbia (AGES) titled Assessment of flood-damaged infrastructures in Bosnia and Herzegovina and Serbia.

This project connects 15 geophysical specialists from nine countries, 32 students and graduates of six universities in four countries (Japan, Serbia, BiH and Montenegro), local geophysical contractors, engineers and politicians of local governments, as well as residents of the local areas in geophysical surveys.

Geoscientists without Borders is an initiative of SEG launched through its Foundation to support

humanitarian applications of geoscience around the world. Projects are often selected in the areas in need of assistance where geophysics can be a tool. The topics include archaeology, water management, pollution mitigation and disaster management due to earthquakes, landslides, tsunami and volcanoes.

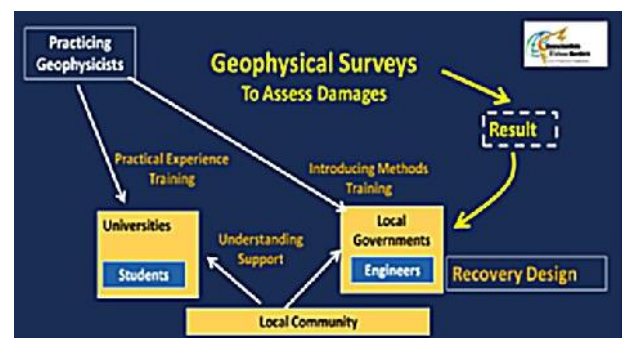


Figure 2. A Schematic diagram of the relationship between stakeholders of the GwB project.

The application of geophysics to landslide areas had been a previous GwB project in Brazil and Sweden in 2010-2011 (SEG website). The current project was selected only a few months after the disastrous rain in response to the application by AGES. It started with a discussion with the local community and site scouting in March 2015, followed by field data

collection in June and September 2015. Twelve geophysical experts, twenty-two students and graduates from Serbia, BiH, Australia, Sweden, Italy and Japan participated in the fieldwork. It was supported by six local governments and many residents of the local community. The outcome will be delivered to the local engineers for designing their recovery plan (Figure 2).

Six locations in Serbia and BiH have been surveyed so far in the project in 2015 (Figure 3). They are evenly spread between Serbia and BiH, and even in BiH, evenly spread between regions within it, considering the sensitivity of both the political and religious background.



Figure 3. Project areas

Methods used and review of results

Ground methods (seismic and electric) were used in order to compute a full set of elastic parameters and map layer boundaries.

Time lapse methodology (6 or more months difference) was also used, to investigate if any reactivation or slide advancement is happening. The base line survey was in the dry period, while the repeated survey was made after the rainy period. Multichannel Analysis of Surface Waves - MASW is a seismic technique used to investigate the underground condition by S-wave velocity distribution. It has been used in many engineering applications in recent years.

Seismic refraction was used to infer layer velocities and invert for layer boundaries. P-wave tomography was computed and combined with refraction interpretation. P-velocity profile was combined with shear velocity profile inferred from MASW measurements to produce profiles of elastic

properties (Young modulus, Poisson's ratio, Lamé's constant Lambda, Bulk modulus). These moduli or typical engineering parameters are related directly to the soil properties, rock strength and quality. Reflection imaging is used to help interpret layer boundaries and their morphologies as well as fine structures such as faults and fractured zones. Electrical resistivity tomography (ERT).

When studying landslides, electrical resistivity tomography (ERT) is a useful method because of the strong contrast in the resistivity between the coarse landslide material and the undisturbed bed-rock, despite some ambiguities that could be introduced during the inversion procedure and the limited resolution at depth. This method also helps by revealing the resistivity characteristics of the subsurface, thereby providing valuable information on groundwater distribution and on the geological structure of the subsurface. By conducting ERT in two phases, firstly in a dry period and secondly after a rainy period, we estimated water-table level by using the relationship between resistivity and water saturation.

Slope stability investigation. In this Project, a geotechnical engineer specialised in landslides will use the data and suggest direction of further investigation and remedial actions. The results will be presented to the local authorities so that they can plan the reconstruction of the damaged infrastructure. The proposed landslide investigation and analysis procedures consist of (1) preliminary investigation, (2) detailed investigation, (3) analyses of landslide mechanism and slope stability, and (4) selection of mitigation measures. In the step (1), collection and review of existing data, detailed site walkover and the topographic study was undertaken. Based on the results of these studies, a detailed geotechnical investigation including the all core borehole drilling, the geologic structure study, surface deformation study, the groundwater monitoring and the slip surface investigation will be carried out.

Geotechnical laboratory testing such as shear box tests and triaxial tests were also undertaken in step 2, in order to determine the residual strength of geomaterials in the slip surface. Based on these geotechnical studies, the identified slip surface will, then, be compared and refined with outcomes of the geophysics investigation.

The data obtained from preliminary and detailed investigations in the steps (1) and (2) will, then,

be used in the following analyses of landslide mechanism and slope stability in the step (3). Based on the results of all the steps, an appropriate landslide mitigation measure will be selected in the step (4). To extend the areas directly covered by the MASW survey and characterize it further, satellite imagery will be used to delineate the landslides boundaries, based on the soil properties and possibly thermal response. Clustering techniques will be used to integrate different geophysical measurements, as seismic, satellite, electro-magnetic and geological surveys.

In 2015, the following localities were investigated:

- Phase I: Valjevo, Zovik and Vrazici (3D)
- Phase II: Lopare, Bajina Basta (2) and Krupanj and in 2016:
- Phase I: Lopare (repeat S+R + new 3D), Novi Seher, Donji Bradic
- Phase II: Valjevo (repeat S+R + new profile, extend 5) (Figure 4).

Results of the complex geophysical investigations performed in Valjevo are presented in Figure 5.

Educating the future generations of geophysicists/geoscientists/environmentalists in BiH and Serbia

Project Assignment Goal was rigorous, theoretical and practical training of 32 students of undergraduate to postgraduate studies (particularly from BiH and Serbia) in application of geophysical methods (e.g., seismic, electric, etc.) in landslide analysis and research on landslide risk management, so to enable them in the future to join the teams of the landslide restoration planners and to conduct their own research and procedures, applying the basic principles of environmental protection and of sustainable development.

Project Assignment Reasons: The endeavour to educate new generations of experts in each scientific and professional field is the essential long-term

goal of any serious scientific and professional organisation. Therefore, one of the relevant aspects of the Project to be realised by AGES, together with their partner organisations and supported by the SEG' Geoscientists without Borders and the local governments where the landslides were investigated, is actually the education of future generations of geophysical experts.



Figure 4. Lines of geophysical measurements in Valjevo

This particularly refers to the students of the universities involved in the Project - who, at the time of initiation of this Project, have the status of active students of undergraduate to postgraduate studies and who are interested in professional development in the fields of applied geophysics, geosciences and environmental sciences, the doctrines without which it is impossible nowadays to get the idea of a high-quality analysis of the areas affected by landslides, conducting landslide risk procedure assessment - particularly in the landslide prone areas, establishing the geological requirements to perform (geo) engineering works of restoration and/or mitigation of the landslide consequences and the like.

The landslide phenomenon, in any local self-government, especially in urban areas, causes multiple adverse effects on people's lives, health and work, as well as on socio-economic development of the community because, in a very short period of time, it leads to extensive degradation of urban infrastructure (e.g., roads, bridges, water supply, sewers, telecommunications, etc.), inflicting significant material damages to the affected local self-governments.

It is not a rare case that massive and/ or frequent landslides make the everyday living completely impossible in the affected areas. Because of the need to have the landslide consequences remedied

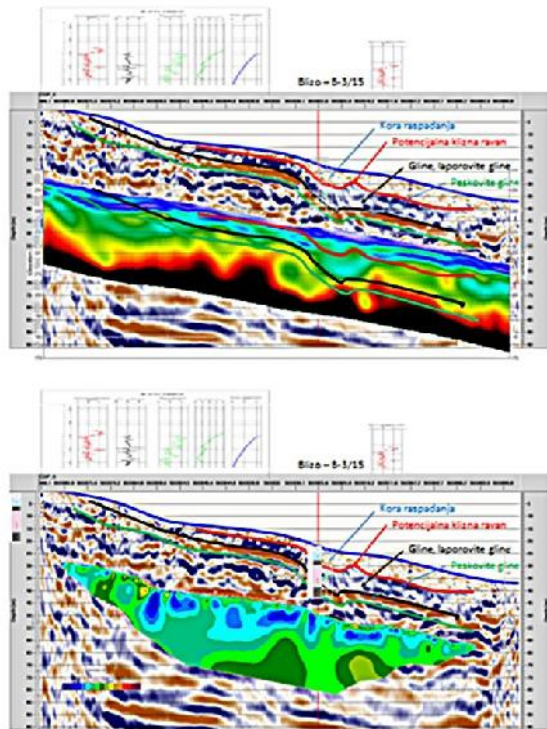


Figure 5. Results of the complex geophysical investigations performed in Valjevo

as soon as possible, the destroyed infrastructure in first place, and to have the normal course of everyday life and work restored in the communities that are located on, or gravitating toward the affected areas, when studying the negative effects of landslides, unfortunately, there are very often omitted the assessments of the negative effects of landslides on the wildlife and environment in the area of a direct or indirect landslide impact.

It was for this reason that, when outlining the plan of education intended for the students who participate in the project, a particular emphasis was put on gaining a sound knowledge in the field of landslide ecology, in addition, of course, to the carefully planned education necessary to master the methodology of geophysical investigation of landslides and acquire the general knowledge of landslides (e.g. types of landslides, terminology, specific features of landslides on local, regional and global scale and the like).

The above said type of integrated education, within which all the methods and doctrines are studied for the purpose of the contribution thereof to

the protection and continual improvement of the environment, is increasingly practised nowadays, since it has become absolutely clear that a healthy environment is the basis of health of every person and of prosperity of the modern civilisation, as constantly pointed out by numerous international organisations dealing with the protection of biodiversity and the implementation of the concept of sustainable development (e.g. UNEP, OECD, WHO, etc.).

Such a type of integrated education involves, among others, the fact-finding and acquiring the skills in project management, developing the skills of outlining the public advocacy of certain ideas, e.g. regarding the importance of providing for the material resources and political will to establish a long-term monitoring over landslides and/or a timely and more complete informing of the citizens about the risk of landslides, and the like.

It is worth noting that the universities involved in the Project have not been chosen at random, but because they provide for education of the students of geology, geophysics, geodesy, architecture, civil, mechanical and electrical engineering, ecology, environmental protection and the like, potentially interested to participate in the Project offering them the acquisition of the theoretical and practical knowledge necessary for the geophysical investigation of landslides and the implementation of the engineering geology techniques intended for restoration thereof.

Project Assignment Sustainability:

1. Making students of undergraduate and postgraduate studies qualified to analyse the landslides by applying the geophysical methods would provide, to BiH and to Serbia as well, a significant number of young geophysics experts who will, in the future, be able to independently work in this field of research for the purpose of the restoration of landslides;
2. The publishing of the monograph, with the emphasis on presentation of the basic elements of the so-called landslide ecology, would fulfil the evident void in the literature in this field in Bosnian, Serbian and Croatian languages, and thus, provide the basic information and support to the education in this significant professional activity.

Conclusions

As a part of the 2015-2016 GwB project of Assessment of flood-damaged infrastructures in Bosnia and Herzegovina and Serbia, a complex geophysical survey has been carried out. The data collected for reflection analysis were analysed by using the MASW method and compared with the results of the geoelectric method.

In the next few months, the reflection and refraction analyses of the same data will be completed, and the electric resistivity profile will be available. A few drilling sites have already been proposed. These data will be integrated into a comprehensive interpretation to contribute to landslide risk analysis. Among several Project Assignment Results related to education, the following ones are very important:

1. To make the students of undergraduate to postgraduate studies qualified to use, on their own, the up-to-date geophysical methods when analysing the landslides and, on the basis of

the application thereof, to assess the risk for repeated landslides, to provide the advice to the geology engineering team within the procedure of landslide restoration planning, taking into account the observance of the fundamental principles of environmental protection and its continuous improvement, as well as the implementation of the sustainable development concept;

2. To make the students qualified to perform, on their own, the scientific-research work in the field, to make use of professional literature, process the results of their measurements, prepare the presentations of such results and the basic draft of the manuscript, as well to publish their scientific results;
3. The Monograph containing the presentation of the basic elements of the landslide ecology, from anthropogenesis and biological consequences of landslides, to presentation of the ecological tools that can be used to restore the biodiversity in the areas devastated by landslides, including the implementation the concept of sustainability and sustainable cities.

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Geolozi bez granica – geonauke u rešavanju humanitarnih problema

SAŽETAK

Nakon obilnih padavina u regionu Balkana (maj 2014. godine) koje su izazvale veliku štetu od poplava u BiH i Srbiji, Asocijacija geofizičara i ekologa Srbije (AGES) pokrenula je, uz podršku SEG (Society of Exploration Geophysicists) programa Geolozi bez granica i lokalne zajednice, humanitarni projekat Procena oštećenja infrastrukture u poplavama u Bosni i Hercegovini i Srbiji. Geolozi bez granica (Geoscientists without Borders) je nov program Fondacije SEG koji sponzorise primenu geofizike i geonauka u rešavanju humanitarnih problema širom sveta. Ovaj program ima za cilj povezivanje univerziteta i eksperata sa lokalnom zajednicom koju je pogodila neka prirodna katastrofa. Cilj projekta je da se kombinuje nekoliko geofizičkih metoda u cilju uspostavljanja najefikasnije metodologije kojom se mogu definisati i sanirati postojeća klizišta i sprečiti nastanak novih. Kombinacijom nekoliko geofizičkih metoda, kao što su: seizmičke (reflektivna, refraktivna, MASW), električne, EM i satelitske metode, dobijeni su rezultati koji će biti predstavljeni relevantnim lokalnim vlastima i na osnovu kojih će se predložiti mere sanacije ispitanih klizišta. Kroz multidisciplinarno partnerstvo i saradnju AGES i lokalne zajednice sa stručnjacima iz poznatih svetskih institucija koje se bave inženjeringom i geonaukama, globalna geofizička zajednica će se značajno ojačati. Takođe, obuka studenata u primeni geofizičkih metoda je još jedan aspekt projekta. Studenti osnovnih i posleđiplomskih studija koji su uključeni u rad na terenu, kao i obradu i interpretaciju podataka, sagledaće praktične aspekte i značaj geofizike. Ovi studenti će biti sledeća generacija geofizičara koji će se baviti predviđanjem i sprečavanjem sličnih katastrofa na lokacijama sklonim pojavi klizišta širom regiona.

Ključne riječi: Klizišta, Geolozi bez granica, Srbija, BiH.