

Case Study: Landslides in Ciudadela Reinaldo Espinosa, Loja, Ecuador

Introduction

Ciudadela Reinaldo Espinosa is a community located in the Loja basin of Ecuador, that includes the north-south trending valley of the same name. The basin is limited to the east by the Cordillera Real and to the west by the Cordillera Occidental.



Fig. 1. Panoramic view of the unstable area in Ciudadela Reinaldo Espinosa.

In 2003 the province of Loja was surveyed and evaluated for slope instability in order to categorize the degree of hazard and vulnerability for subsequent detailed geological studies in areas designated as potentially unstable. Ciudadela Reinaldo Espinosa was selected by the national geoscience agency of Ecuador (DINAGE) as their pilot project study area within MAP:GAC because it has been affected by slides since 2001 that have caused damage to housing, but have not yet caused loss of human lives. Motion has been rapid but not catastrophic, and consists of sections of the slope sliding or flowing downhill. Residents describe parts of their houses separating by approximately 1 metre over a 2-month period. Wall fractures and skewed house frames are common, and in some cases entire sections or walls of houses were toppled by the deforming ground. Brief studies by geotechnical experts and geologists of the Loja area, and the basic observation that ground movement correlates with prolonged periods of rainfall, suggest that an elevated water table can trigger land movement. The community is currently attempting to install a drainage system to lessen future movement, but it is unclear whether this is the best solution or how likely it is to work in the long term.

The broader area around Reinaldo Espinosa is currently undergoing rapid urban growth as an extension of Loja, adding to the importance of the pilot area's technical research. This work will contribute to establishing measures of prevention and mitigation to help minimize the effects of future slides in areas beyond Reinaldo Espinosa, where the geological and geotechnical factors are comparable, and similar instability issues are likely (Fig. 1).

No movement has been detected in the study area in the last year or so, perhaps due to an unusually dry period, but it is of vital importance to consider that urban growth and construction of housing and other infrastructure in the area will increase vulnerability in the future, and that historical slide areas are often known to resume activity.

Geologically, the area is composed of young, surficial deposits derived from erosion of Miocene to Pleistocene clastic sedimentary rocks including conglomerates to shales. Within the Loja basin, the sedimentary sequence is in nonconformable or discordant (faulted in some places) contact with Paleozoic metamorphic basement rocks, although in the study area the unconformity is not exposed. The intermontane Loja basin is one of many marine to continental transitional sedimentary basins located in the southern extension of the Cordillera Real.



Fig. 2. Workshop on the use of differential GPS.

Activities Completed

In accordance with the timeline of activities for MAP:GAC and with its technical assistance, Ecuador's Ministry of Energy and Mines (MEM) through DINAGE and the contributions of the Regional Program for the Development of Southern Ecuador (PREDESUR), the Private Technical University of Loja (UTPL), the National University of Loja (UNL), the Loja Regional Department of Mining (DIREMIL), and the Provincial Council, began work in the Ciudadela Reinaldo Espinosa in the city of Loja, utilizing differential GPS for the establishment of control point locations and subsequent monitoring of the region.

Work in the area took place between April 27 and May 3, 2004. The first few days included a workshop for staff of DINAGE and participating regional institutions on the use of differential GPS in the Loja offices of MEM (Fig. 2). This initial work included establishing a base station location on the roof of the MEM office building, from which all ground reference and monitoring stations were measured. This location will be used well into the future for a variety of studies. The group then proceeded to the field to apply this technique in Ciudadela Reinaldo Espinosa and along the Loja-Zamora highway.

The first activity in the field was a meeting with the community, including the local neighbourhood leader, and all were very open to the work and committed to participating and collaborating with the group (Fig. 3).

In the area of Ciudadela Reinaldo Espinosa, one monitoring station was installed, and 15 control points were measured in locations previously identified in aerial photographs (Fig. 4). A longitudinal profile was also created from the main scarp to the foot of the slide, as well as two cross sections of the affected area (Fig. 5).

The ground control data obtained in the field will serve as a basis for the creation of digital elevation models (DEM) of the area using the existing 1:5000 air photographs. Based on initial data processing, the control point locations have a precision of better than 2 cm in almost all cases. These results should allow for the creation of a DEM with spatial resolution better than 2 m, and will permit reliable slope stability analyses. The monitoring station, which was established on one of the houses that has suffered from the ground movement, will be remeasured periodically over the next year, probably every few months. The initial measurements were taken carefully, establishing an initial location with a precision of about 2 mm – a very high quality result for this technique. Continuing measurements will help to determine the causes of the mass movements in the region, for example by correlating measured movement with rainfall. In addition, the measurements will provide confirmation that any installed drainage of groundwater is (or is not) actually an effective mitigation strategy. One complication of this monitoring effort is that the ground motion in the past has been discontinuous in time, and irregular spatially. For example, parts of the slope moved while others were apparently completely stable. It is likely, therefore, that additional monitoring stations will need to be established in the near future. For the moment, however, the station established during the initial GPS surveying will allow the technical team to determine a baseline of data on which to base, and assess, further work.



Fig. 3. Reinaldo Espinosa community leader with Canadian expert, Dr. Mark Stasiuk, and Ecuador's National MAP:GAC Leader, Ing. Elias Ibadango.



Fig. 4. Differential GPS monitoring station.

Conclusions

The ground motion that occurred in 2001 in Ciudadela Reinaldo Espinosa was heterogeneous.

The movement appears shallow and limited to the sedimentary sequence and possibly only the surficial deposits.

The movement correlates with an abundance of water, both meteoric and groundwater.

The conglomerate deposits existing in the area would be capable of forming aquifers between the impermeable siltstone and shale layers and facilitating their movement.

Future Plans

Using the ground control points to make periodic measurements of the mass movement in the area, the planned course of action includes evaluating the data from the differential GPS in order to better understand the processes in the region, and whether any mitigation strategies are working.

A geological and geotechnical study of the area will be carried out on both the surficial deposits and the bedrock. This will include a qualitative evaluation of their physical and mechanical properties in situ, a laboratory analysis of samples, and a quantitative calculation of stability using the derived digital topography.

The researchers will create models of various scenarios considering the possible areas of impact in the case that a sudden slide occurs within the unstable area, or if gradual motion starts again.

Additionally, a socio-economic study of the area of influence will be undertaken in order to establish a direct relationship between the group of researchers and the community. It is necessary to create a working relationship in advance of an event, as it is difficult to apply wise and informed decisions regarding regional and land-use planning without the direct participation of the community affected.



Fig. 5. Technicians creating a transversal profile in the slide area. Note steepness of slope and hummocky topography.