AN INTER-DISCIPLINARY APPROACH TO LANDSLIDE HAZARD ASSESSMENT AND MONITORING

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THE LANDSLIDE EVENT

One of the largest landslides in Austria over the last years occurred on the Rindberg near Sibratsgfäll in the federal state of Vorarlberg (Austria), where about 70 million m^3 of soft rocks and an area of 1,4 km^2 was involved in a hazardous mass movement, destroying 15 buildings completely. A short period of heavy precipitation and the rapid melting of snow in spring of 1999 initiated this catastrophic landslide on the South-flank of the Rubach Valley. The movement rates of rock- and debris bodies involved exceeded up to 1m per day.

THE STRATEGY

As a follow up of this catastrophic landslide a strategy to deal with similar events was worked out by order and in cooperation with the Forest Technical Service for Torrent and Avalanche Control of Vorarlberg based on the evaluation of applied measures. It turned out that airborne geophysical measurements are a valuable tool to get a quick overview of the geological situation, to detect areas susceptible to a high sliding risk, to assist the follow up geological and hydrological mapping program and to optimise planning of further (ground)-geophysical surveys. Within a second step ground geoelectrical surveys were used for advanced understanding of the internal structure of the landslide. The location of survey lines was planned according to the resistivity pattern derived from the airborne electromagnetic survey. Based on these findings and on the results of a geo-hydro-logical mapping program, boreholes were drilled to calibrate the geoelectrical results and to determine the geotechnical parameters of soil samples. Additionally geophysical logging and hydrophysical logs were performed. Based on all of these results a geotechnical subsurface model was set up and parameters and conditions of safety and failure were calculated. Finally a multi parameter monitoring network was set up and maintained now for four years.

AIRBORNE GEOPHYSICAL SURVEY AND REMOTE SENSING

A high resolution, multi-parameter airborne survey was performed, using electromagnetics, magnetics, gamma ray measurements, soil humidity and infra red sensors. Electromagnetics turned out to be the most important parameter to investigate large scale landslide areas. Using this method a conceptual model of the subsurface structure could be derived. The results were

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very valuable for mapping geologists as they helped to optimise mapping procedures and to minimise actual field work, which is often very difficult and time demanding in the rugged terrain of sliding slopes.

GROUND GEOELECTRICAL SURVEY AND GEOTECHNICAL MODEL

The outcome of the airborne survey furthermore helped to optimise the location of a ground based geoelectrical campaign. Several km of multielectrode profiles were carried out to constrain the inversion of the airborne electromagnetic data and to determine the detailed internal structure of the sliding area. The results could be calibrated after drilling of several deep boreholes and the application of borehole electromagnetic logging.
Based on the subsurface model derived from the geoelectrical results, geotechnical calculations proved that soil water content is the driving factor for movement of this landslide. According to situations of high or low water level different scenarios of failure resulted, thus underlining the importance of monitoring the subsurface water regime for risk estimation.

THE MONITORING SYSTEM

As changing hydrological conditions are reflected mainly in a variation of saturation, the geoelectric method, whose determining parameter Resistivity mainly depends on porosity, saturation, pore fluid conductivity and clay content, could be a reliable tool for observing such changes. Consequently a multi-parameter monitoring system was designed. The core part of the development was focused on the design of an innovative geoelectrical monitoring system.
The monitoring system has now been in operation since 2002. The data is sent daily by email to the central data base in Vienna. The geoelectrical system is supported by meteorological monitoring instruments, soil temperature and soil humidity measurements at different depths, inclinometric measurements, GPS time lapse positioning and hydrological monitoring. Results of four years of monitoring show a clear correlation of Resistivity and self potential anomalies with phases of increased movement.

CONCLUSIONS

Several methods have been tested to investigate and survey landslide areas after the big landslide event in Sibratsgfäll. The resulting optimise strategy consists of the combined application of airborne electromagnetics, ground geoelectrical measurements and geoelectrical monitoring combined with hydrological and geological mapping and geotechnical modelling. It has further to be pointed out that interdisciplinary communication and discussion was the primary key to access this complicated hazard situation.

Keywords: Landslides, mitigation strategy, geophysics, monitoring.