# Landslides affecting the Vía Interoceánica, East of Quito, Ecuador

KATRIN SILVERS[1] & JAMES GRIFFITHS[2]

[1] *Mouchel Parkman. (e-mail: katrin.silvers@mouchelparkman.com)*
[2] *SEOES, University of Plymouth. (e-mail: j1griffiths@plymouth.ac.uk)*

**Abstract:** Quito, the capital of Ecuador, is surrounded by steep and unstable terrain, and landslides are a common hazard that often cause damage to the infrastructure, especially roads. In this study failures along a strategic tranportation route, the Vía Interoceánica, are investigated. This is the only road linking Quito, and the entire northwest of the country, to eastern Ecuador. A series of failures occurred on the road leading up to its closure in 1999. The question is why a road was attempted in an area where the costs of construction and maintanance were liable to be so high? The conclusion is that road construction in Ecuador is not just a geotechnical issue as influential individuals or sectors can bring political pressure to bear to ensure construction takes place in specific areas. In the case study presented the result was a rapid transit road link between high socio-economic status neighbourhoods and the capital.

**Résumé:** Quito, la ville capitale de l' quateur, est entourant par le terrain raide et instable. Glissements de terrain est un hasard général que cause la dommage de la infrastucture, et les rues en particulier. Par cette étude, glissements de terrain le long d'une route de transporation stratégique, la Via Interoceánica, sont recherchant. Cette rue articule du nort-ouest de l' quateur entier avec l'est de la pays. Une série de glissement de terrain s'est présenté sur la rue avant elle a fermé en 1999. La question est pourqui une rue a essayé dans une localité où le prix de la construction et maintain était formidable? La conclusion est pour l' quateur la construction d'une rue ce n'est pas seul une probleme géotechnique parse que les individuels ou la société locale déteriminent la pressure politique assurer construction se passe en les zone spécifiques. En cette étude, le résultat était une rue de passage rapide entre les voisinages de statut grande et la ville capitale.

**Keywords:** Landslides, geological hazards, risk assessment, mapping, Ecuador

## INTRODUCTION

Quito, the capital of Ecuador, lies approximately 10 kilometres south of the Equator, some 2800 metres above sea level (Buvier et al, 1999). It is situated on the lower slopes of the active volcano Pichincha (elevation 4794 metres) in the Interandean Depression at the Eastern edge of the Cordillera Occidental, the western range of the Ecuadorian Andes (Fig. 1). The surrounding area is marked by steep and unstable terrain, and landslides are a common hazard (Benitez, 1989; Dávila, 1992) that often cause damage to the infrastructure especially roads.

The road examined in this study is the Vía Interoceánica, and the results are based on a field investigation undertaken in July-September 2000. The Vía Interoceánica is a crucial strategic transportation route as it is the only road linking Quito and the entire northwest of the country to eastern Ecuador, an area known as the Oriente or Amazonía. It is also the main and shortest connecting road between the North of Quito and Cumbayá, both highly populated areas (Fig. 2). The history of development of the Vía Interoceánica is presented in Table 1.

 

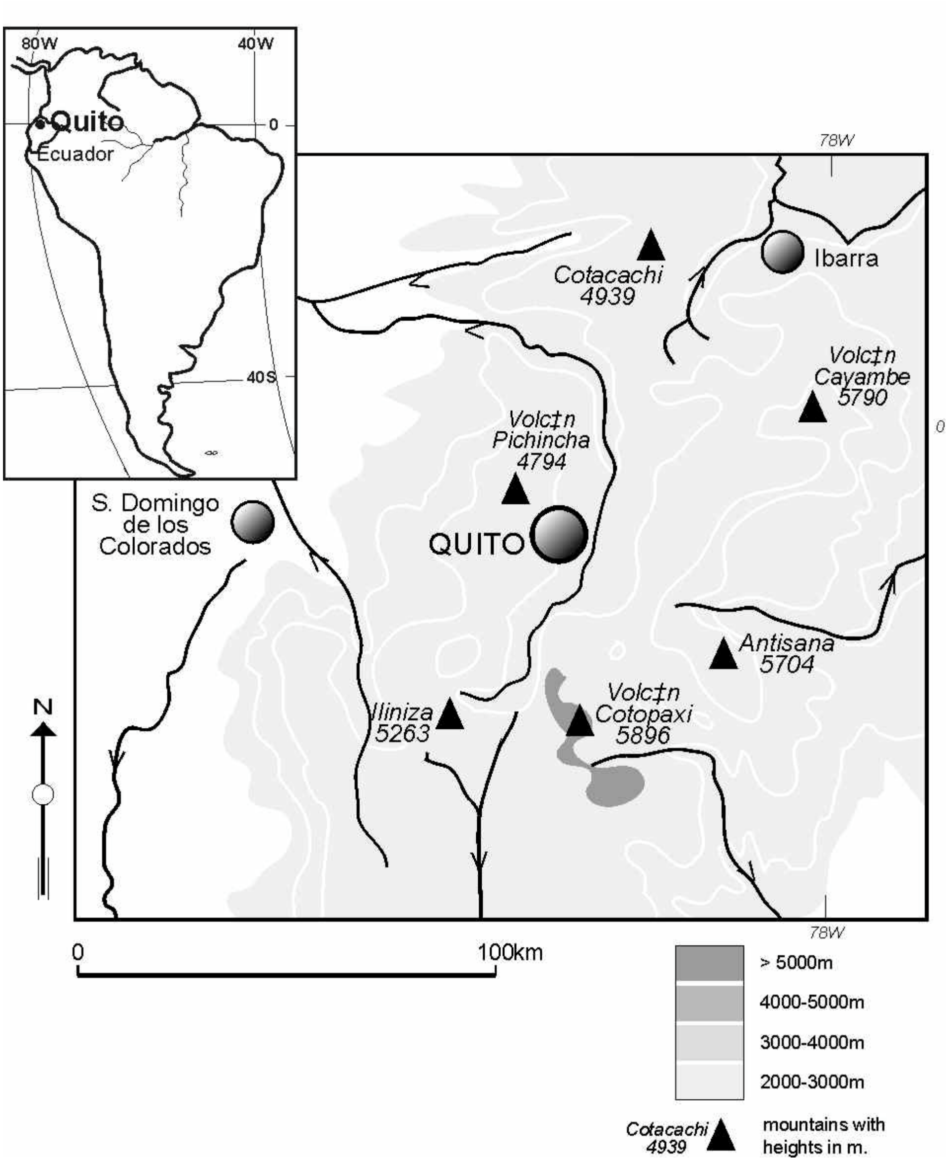


**Figure 1.** General location map of Ecuador and Quito

**Table 1.** Development of the Vía Interoceánica 1960-2000

| | |
|---|---|
| 1960s | 6 metres wide; vertical cut slopes up to 5 metres high; use of rounded river cobbles for road pavement. Initial construction was encouraged by the need to access an aggregates quarry. |
| 1970s | 1st widening to 8 metres; construction of the Machangara bridge (entry to Cumbayá) and urban settlements of high status (Miravalle); first landslides occur on the road; repair works result in increased vertical cutting heights. |
| 1980s | Final widening to 3 lane road 14 metres wide; vertical cuttings up to 15 metres high; construction of improved bridge at Cumbayá; increasing property values in the urban developments. |
| 1990s | Traffic usage increases significantly (university, urban developments, shopping centres, and leisure facilities in the valley); in parallel there is increased demand for construction materials resulting in large-scale exploitation of the existent quarry on the road. Large-scale landslides on both sides of the road destroy large parts of the roads, resulting in repair works and increased vertical cuttings up to 25 metres high (with 2 benches). Finally landslides occurred in 1999 leading to closure of the road. |
| 2005 | After six years of closure, the Vía Interoceánica (the investigated stretch now referred to as Vía Interoceánica Oswaldo Guayasamin) was re-opened on 10 August 2005. To avoid further instability problems a tunnel has been excavated through the northern slope. |

## ENGINEERING GEOLOGY & GEOMORPHOLOGY

The general geology of the Quito region is characterised by predominantly Quaternary volcanic and sedimentary rocks (Sauer, 1943, 1971). Three principal geological processes are reflected in the local geology: tectonic uplift and extension associated with the continuing development of the Andes, vulcanicity during the late Tertiary to Quaternary Periods, and glacial activity resulting from climatic variations during the Pleistocene (Coltorti and Ollier, 2000; Clapperton, 1987).

The area of particular interest to this study lies in the Interandean valley to the east of Quito and south of the Bellavista Plateau (Fig. 2). The plateau is composed of Quaternary lacustrine deposits, at an average elevation of 2900 m, overlying Tertiary volcano-sediments with lavas. Rivers have eroded down through the plateau and within the study area the relative relief is generally very high with the base of the gorge of Quebrada del Batán Grande (Fig. 3) lying below 2600m. Generally the landscape is marked by steep slopes, cliffs and deep gullies. In places large-scale translational landslides have formed on the edge of the plateau, notably the Guápulo landslide with debris upto 800m thick. The gullies form a complex and dense drainage system, with evidence of rapid erosion, especially during the wet season (average annual rainfall is between 1000 and 2000 mm with highest values in February-April and October–November). The heavy rainfall during this period (maximum 30-minute intensities have a mean value of 40 to 45 mm/h; de Noni et al, 1986) causes gully formation and is strongly linked with the occurrence of landslides and other natural hazards such as flooding.

The section of the road subject to investigation was the initial part of the Vía Interoceánica that runs along the northern slope of the Quebrada del Batán Grande almost up to the joining point of the Batán Grande with the river Machángara. The two incised rivers form the alignment for the principal transportations route from central/northern Quito to the Interandean valleys. The valley-side slopes are generally very steep with slope angles of 30 to 70 degrees, forming a gorge. A double waterfall approximately 500 m from the Aurelio Dávila Cajas Bridge and about 100 m in height is the dominant feature of the gorge (Fig. 3 and 4). The steep valley-side slopes have necessitated the excavation of deep cutting slopes on the road, up to 25 m in height. The hills on both sides of the Batán Grande gorge are urbanised with many high quality high-rise buildings built for the upper socio-economic class groups and linked by the Aurelio Dávila Cajas Bridge. However, there are also a number of shanty settlements on the upper northern slope below Bellavista Plateau and some along the road on the lower northern slopes.

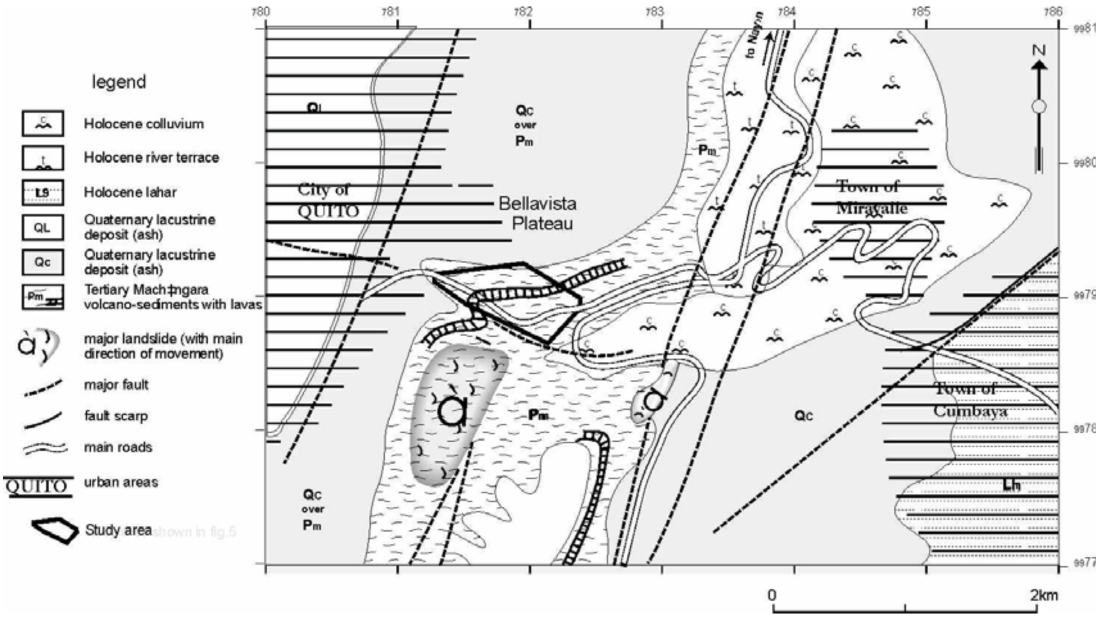


**Figure 2.** General geology of the study area

**Figure 3.** The Quebrada del Batán Grande gorge and waterfall

Since the Vía Interoceánica became a regular routeway for traffic in the 1970s it has been continuously affected by landslides. As the carriageway has been widened to accommodate increased traffic flow, mass movements have increased in size and frequency. The main failures along the studied section took place in the vicinity of the waterfall. In 1998 a landslide destroyed a substantial part of the road (El Comercio, 1999a, 1999c). The section was remediated, which involved an increased cut of 6m horizontally into the slope and thus increasing cutting heights to the present 25m. In April 1999 rainfall, described as heavy (El Hoy, 1999), triggered another landslide in the same section on the upper slope, which caused the death of one person and injured another. The road was temporarily closed but was reopened after only one week, although the risk of further failures was recognised (El Comercio, 1999b). The measures taken to reduce the risk were the closure of the lane immediately beside the cutting slope and restriction of vehicular access to light traffic only (El Comercio, 1999a). However, a major landslide later that year blocked this section and thus the road in its form at that time had to be permanently closed. The road was not reopened until August 2005 when, to avoid further instability problems, a tunnel has been cut through the slope. At 1,334m in length and 11.1m width it is the biggest tunnel in Ecuador. Total investments for the tunnel were in the region of US$33 million. Use of the tunnel will cost US$ 0.40, which will be used for its maintenance.

Geomorphological mapping for this study was carried out in August 2000, using the methods recommended by Cooke & Doornkamp (1990), and identified two landslide systems (Fig. 4 – at end of paper):

- System 1 was located on the upper slope between 470 and 670 metres from the bridge and involving more than seven translational landslides. The failure that blocked the road at the end of 1999 was by far the largest. The scar of this failure extended 80 metres across and from 25 to 65 metres above the road. It destroyed the upper 10 – 12 metres of the designed rock cut slope. An estimated volume of over 30,000 $m^3$ of material was displaced, completely blocking the road. Some of the debris cone was also displaced by other failures down to the riverbed. Observations of broken estate walls on the upper slope slightly east of the area (at 725 m from the bridge) suggested that the failure had started with small-scale creep movements.
- System 2 involved the retreat of the northern face of the waterfall and was found on the lower slope between 450 and 630 metres from the bridge. Four metre deep tension cracks in the crown of the failure were located in the road pavement, and a near vertical rock face suggested that this retreat took place primarily as rock falls.

System 2 appeared to be continually active. In an aerial photograph of the site taken in 1996, the landslide backscar was located at 10 metres from the road. In 1998 the pavement of the Interoceánica became involved in movements (El Comercio, 1999a). A new design shifted the road another 6m horizontally into the slope, nevertheless it became subject to failure again in 1999 and an additional 5m of the carriageway was lost by the beginning of August 2000. During the period of field investigation the maximum rate recorded was approximately 5 metres per month. This very high rate could have been triggered by the heavy road clearing works carried out during that period. The extent of the damage to the road by September 2000 is illustrated in Fig. 5.

## FINANCIAL AND POLITICAL ISSUES

A number of technical factors have contributed to making the Quito-Miravalle road section a highly unstable part of the Vía Interoceánica, such as the angle of the slopes, the weak underlying materials, the intense precipitation and river undercutting. These factors are independent of human activity and raise the question of why was an engineering project of the size of the Vía Interoceánica built on these slopes, given the geological and geomorphological conditions?

**Figure 5.** Instability that closed the road in September 2000

In a developing country like Ecuador, it is not surprising that cost is a critical determining and limiting factor on the final construction design of a highway. Engineering geologists and civil engineers have long been aware of the instability problems related to road construction in mountainous regions (Fookes et al, 1985; TRL, 1997). Yet, in Ecuador, contractors do not always incorporate all the recommendations into the final road design since they are associated with increased costs. This is despite clear guidelines being provided by the Ministry of Public Works and Communication (MOP, 1980, 1993). As discussed in Febres Cordero (1996) and Vera (1985), one of the fundamental problems appears to be the management of limited financial resources according to personal rather than national interests. Although the authorities often provide adequate sums for road construction and use inspectors to oversee the development, some roads have been built with only just enough resources to make them functional for a limited period and to 'look good'. Construction often takes place with the minimum quality and amount of materials, and as quickly as possible. In the case of subsequent road damage, for example from slope failure, it is usual for the same contractor that built the road to be re-employed for maintenance works. Therefore, despite any contract specifications there is little incentive in the original works to construct a road beyond the absolute minimum standards.

In addition slope stability is not seen as a major issue, and drainage control or slope support systems are rarely employed, except where unstable slopes affect wealthy areas. An example is provided by the neighbourhood located to the north of Miravalle (Fig. 2), considered the most expensive urban development of the area. Unstable slopes generated by the construction of a major highway, the Nueva Vía Oriental (NVO), threatened this area and the extent of slope stabilisation works in this section of the NVO is considerable, including drainage control measures, retaining walls and benched cutting slopes. This represents a major investment by the authorities, and is a scenario that has been repeated on the Vía Interoceánica with the construction of the 1.3km tunnel opened in August 2005.

Landslides in the Ecuadorian mountainous region rarely attract much attention, as they are an integral part of its geomorphology. That human activity can affect slope stability both positively (slope stabilisation measures) and negatively (e.g. undercutting, overloading) is not a familiar concept to most Ecuadorians. This is despite the fact that spreading urbanisation of the Quito suburbs has increased the number of landslides and other damaging 'geohazard' events (Peltre, 1992; Godard, 1990; de Noni et al, 1986). Landslide events are generally taken for granted and only nature is held responsible, the 'Act of God syndrome'. Consequently, slope stability is not seen as a political issue.

However, the transportation system is one of the most central political concerns. Highways and their construction are considered symbols of power because they are such high profile features of infrastructure development; therefore, they may be subject to political manipulation by both individuals and companies. The industrial and financial sectors are often the main sponsors of political campaigns. Yet, such sponsorship is viewed as an investment and some reward or repayment is expected (Ayala Mora, 1985; Rosero, 1995). Given the prestige associated with the transportation sector, repayment commonly involves some facet of the traffic network. An insight into Ecuadorian culture and politics is provided by the case studies of corruption and misuse of power in Ecuador discussed by Febres Cordero (1994) and Vera (1985), which supports the idea that political pressure is a major influence on the road construction program.

# CONCLUSIONS

Road construction in Ecuador is not just a geotechnical issue. Any geotechnical issues can be solved using modern construction techniques, although it should be recognised that in Ecuador there is a lack of public awareness regarding the effect of slope failures on road safety, thus there is a failure to appreciate the risk. The effect of political pressures on road construction is both more complex and insidious. These are the result of the particular social and economic circumstances in Ecuador. This includes the use of public resources to reward political sponsorship, and the pressure that influential individuals or sectors can bring to bear. Public projects such as the Vía Interoceánica become reality not only because of necessity, although the Quebrada del Batán Grande does represent one of the few exits from the plateau of Quito to the valleys, two highly populated areas. Even more important, however, has been the influence of residents in high socio-economic status neighbourhoods in Miravalle, exerting pressure on the authorities about extensions and improvements to the road. It was the only part of the valley not directly linked to Quito, with the only previous connection being via Nayõn to the north (Fig. 2). Given this situation, it was inevitable that a road would be built in this location. Similarly, given the geotechnical problems, it was likely that the level of risk would be under-estimated and that, in time, a landslide would cause the road to be closed, leading to an even more expensive solution.

**Acknowledgements.** The authors gratefully acknowledge the input to this paper provided by the following: Michael Silvers for support during fieldwork in Ecuador and in preparing drafts of some of the diagrams; John Abraham of the University of Plymouth for producing the final copies of the figures; and Dr Martin Stokes for his comments on the draft manuscript.

Corresponding author: Prof. James S Griffiths, SEOES, University of Plymouth, Drake Circus, Plymouth, Devon PL4 8AA, United Kingdom. Tel: +44 (0) 1752 233100. Email: j1griffiths@plymouth.ac.uk

# REFERENCES

AYALA MORA E. 1985. Lucha Política y Origen de los Partidos en Ecuador. *Corporación Editora Nacional*, Quito, Ecuador (in Spanish).

BENITEZ, A.S. 1989. Landslides: Extend and economic significance in Ecuador. In Brabb & Harrod (eds) *Landslides: Extent and Economic Significance*. Balkema, Rotterdam, 123-126.

BUVIER, C., AYABACA, E., PERRIN, J.L., CRUZ, F., FOURCADE, B., ROSARIO, S. & CARRERA, L. 1999. Variabilites temporelle et statiale des averses en milieu andin: exemple de la ville de Quito (Equateur). *Revue de Geographie Alpine*, **3** (in French).

CLAPPERTON, C.M. 1987. Glacial Geomorphology, Quaternary sequences and paleoclimatic inferences in the Ecuadorian Andes. In: Gardiner, V. (ed.), *International Geomorphology*, *Part II*, 843-870.

COLTORTI, M., OLLIER, C.D. 2000. Geomorphic and tectonic Evolution of the Ecuadorian Andes. *Geomorphology*, **32**, 1-19.

COOKE, R. U. & DOORNKAMP, J.C. 1990. *Geomorphology in Environmental Management*, A New Introduction. Oxford University Press, Oxford

DÁVILA, A. 1992. Estabilidad geomorphológica de la región de Quito. In: *Atlas Infográfico de Quito: socio-dinámica del espacio y política urbana*. Instituto Geográfico Militar, Instituto Panamericano de Geografía e Historia and Institut Francais de Recherché Scientifique pour le development (in Spanish).

EL COMERCIO. 1999a Urcuquí sin carretera por la lluvia. *El Comercio*, 30.04.1999, Quito-Ecuador, A1 (in Spanish).

EL COMERCIO. 1999b. En la Interoceánica el riesgo es latente. *El Comercio*, 05.05.1999, Quito-Ecuador, B8 (in Spanish).

EL COMERCIO. 1999c. Las autopistas siguen inestables. *El Comercio*, 24.06.1999, Quito-Ecuador, B8 (in Spanish).

EL HOY. 1999. Derrumbe deja un muerto en Quito. *El Hoy*, 30.04.1999, Quito-Ecuador, 3A (in Spanish).

FEBRES CORDERO, F. 1996. *De Flores a Flores y Miel: Breve Historia del Ecuador*. Ojo de Pez Edimpres (in Spanish)

FOOKES, P.G., SWEENEY, M., MANBY C.N.D. & MARTIN, R.P. 1985. Geological and geotechnical aspects of low-cost roads in mountainous terrain. *Engineering Geology*, **21**, 1-52.

GODARD, H. (coord.) 1990. Crecimiento de Quito y Guayaquil: estructuración, segregación y dinámica del espacio urbano. *Estudios de Geografía*, **3**. (in Spanish)

MOP (Ministry of Public Works and Communication). 1980. *Trazado y Diseño Geométrico*. Dpto. Entrenamiento y Publicaciones, Quito (in Spanish).

MOP (Ministry of Public Works and Communication). 1993. *Especificaciones Generales para Construcción de Caminos y Puentes*. Dpto. Entrenamiento y Publicaciones, Quito (in Spanish)

NONI, B.G. DE, FERNÁNDEZ. M.A. & PELTRE, P. 1986. Accidentes Climáticos y Gestión de las Quebradas de Quito: Análisis de "aluvión" de La Raya del 23 de Enero de 1986. *Paisajes Geográficos* (Centro Panamericano de Estudios e Investigaciones Geográficas), **17**, (in French).

PELTRE, P. 1992. Riesgo morfoclimático historico. In: *Atlas Infográfico de Quito: socio-dinámica del espacio y política urbana*. Instituto Geográfico Militar, Instituto Panamericano de Geografía e Historia and Institut Francais de Recherché Scientifique pour le development (in Spanish).
ROSERO, A. 1995. Capitalismo Salvaje y Ausencia de Proyecto Nacional. *Buscando America*, **5**, 37–46 (in Spanish).
SAUER, W. 1943. Memoria Explicative del Mapa Geologico del Ecuador. *Annals Universidad Central del Ecuador*, **71**, 5-34, (in Spanish).
SAUER, W. 1971. *Geology von Ecuador*. Gebruder Borntrager (in German)
TRL, 1997. *Principles of Low Cost Road Engineering in Mountainous Regions*. TRL Overseas Road Note 16, Transport Research Laboratory, Crowthorne
VERA, P.J. 1985. Por la plata baila el perro. *Editorial el Conejo*, Quito-Ecuador (in Spanish).

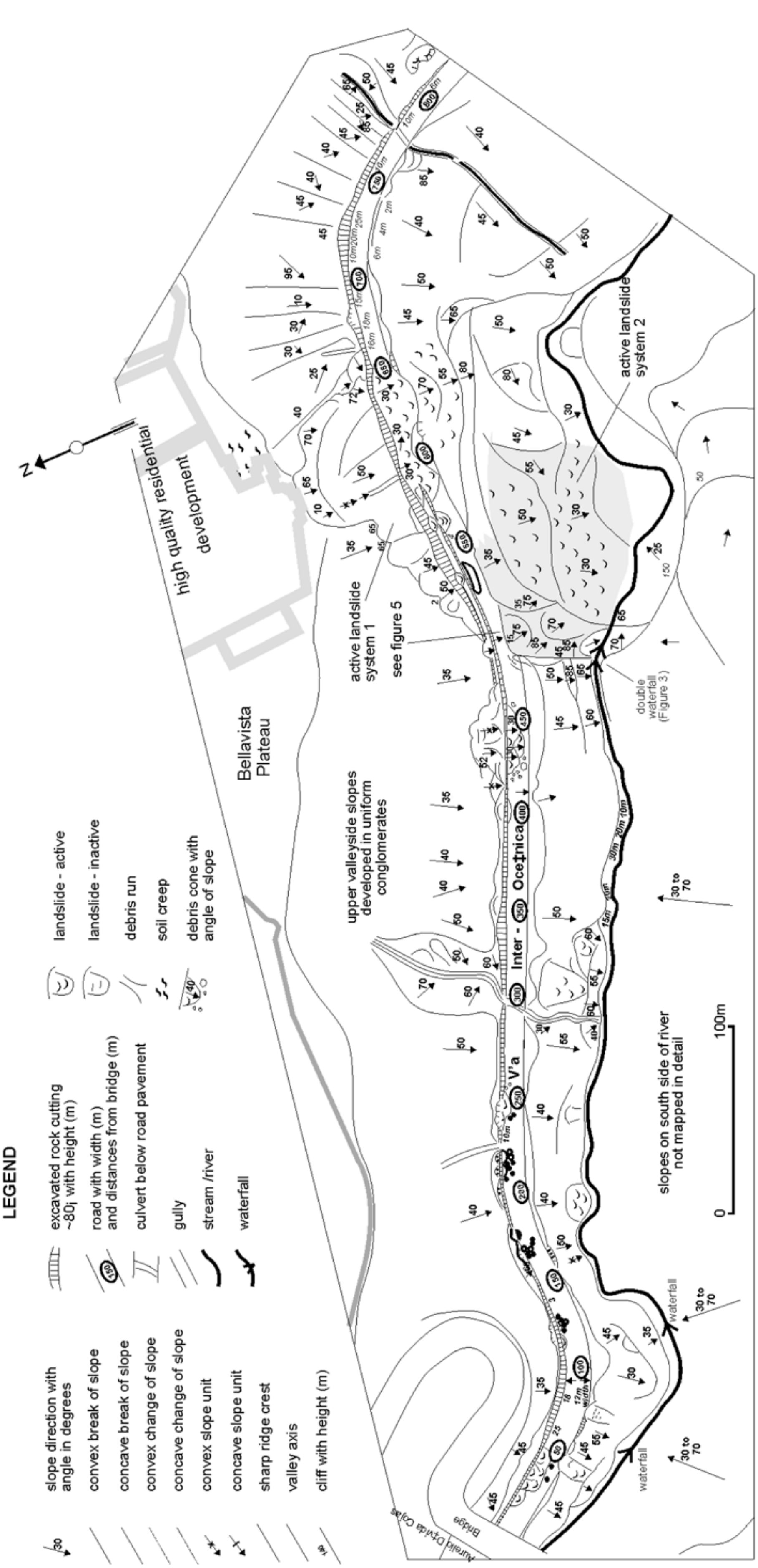


**Figure 4.** Engineering geomorphological map of the study area shown in figure 2