

**GEOLOGICAL SURVEY DEPARTMENT**

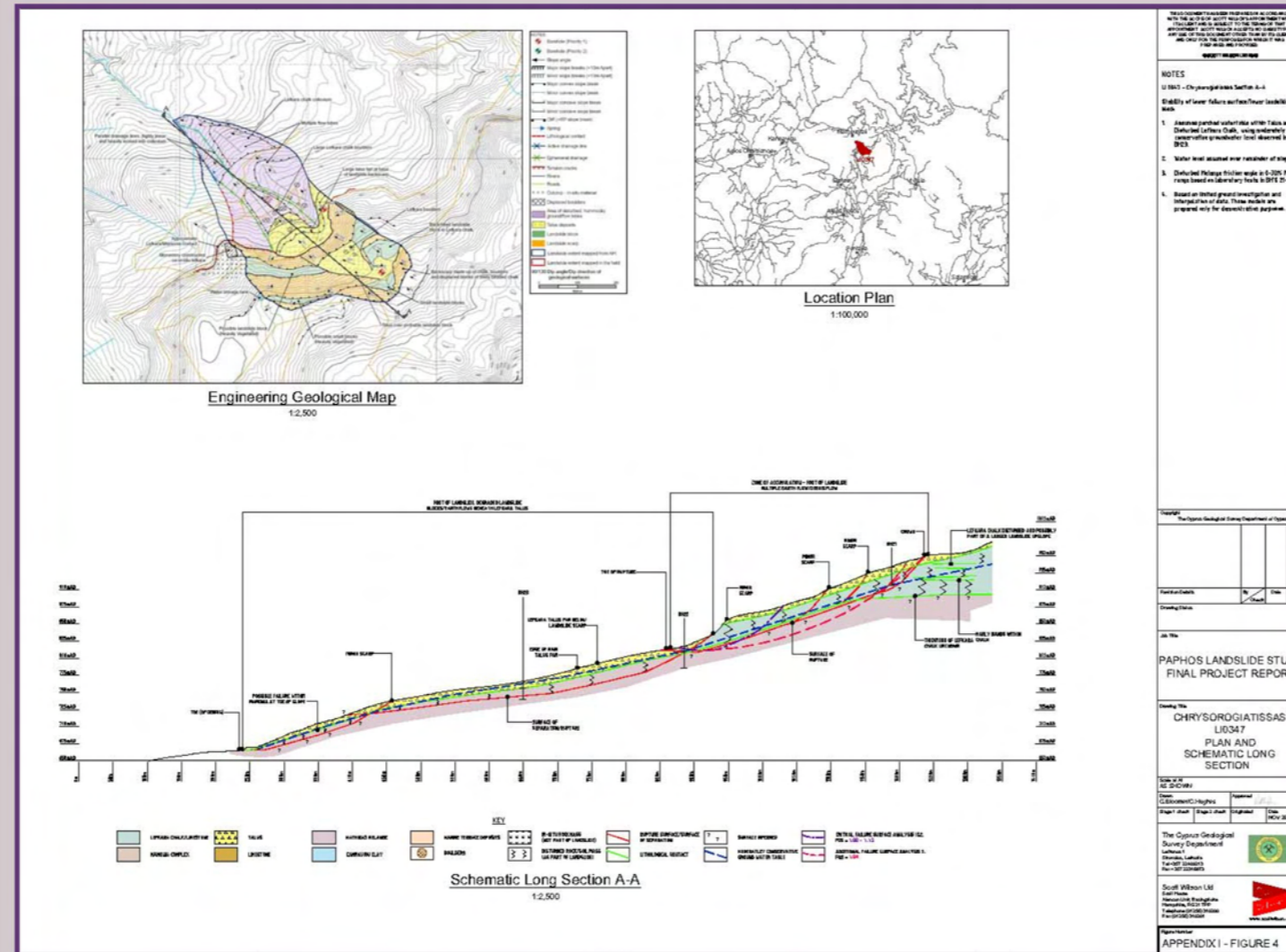
MINISTRY OF AGRICULTURE  
NATURAL RESOURCES AND ENVIRONMENT

REPUBLIC OF CYPRUS



**LANDSLIDES  
IN CYPRUS AND THEIR  
CONSEQUENCES TO THE  
BUILT ENVIRONMENT**

**GEOTECHNICAL MAP AND GEOLOGICAL CROSS SECTION**



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**LANDSLIDES IN CYPRUS AND THEIR  
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**What are the landslides?**

The term "landslide of a slope" means the destabilization of mass layers on a slope and their movement downwards. This movement is caused by the weight of the layers after the disturbance of the equilibrium on the slope. This phenomenon can occur instantaneously and very rapidly, or a slow and progressive movement could happen.

The study of landslides, like all phenomena of slope instability, is a subject of engineering geology, branch of geology. This study in most cases is difficult and complicated due to many causes and factors, which are participating in the creation of landslides, and therefore their treatment is difficult and costly. For this reason it is important always to take preventive measures to prevent the occurrence of these phenomena, rather than face these problems later.

**Main causes of landslides creation**

**Creation of landslides due to natural causes**

The natural causes of landslides are focused in four main groups.

- The type of lithology and generally the geological conditions,
- The topography - morphology,
- The hydrogeological, hydrological regime and the heavy rainfall,
- The seismicity of the region.

Regarding the type of lithology and geological conditions mostly landslides occur on slopes in sensitive clay and / or marly layers, and also in fractured and weak rocks that have undergone previous tectonic processes during the movement of tectonic plates. Such rocks are those belonging to the Mamonia Complex and are found widely in Paphos district.

Landslides also occur in sedimentary rocks like chalks and sandstones or other rocks of Mamonia Complex, which have as basement clayey soils. These rocks are fractured and suffer from landslides due to the continuous changes of the mass volume of clayey soils by changing their natural moisture content.

Limited landslide phenomena occur in rocks of the Troodos Ophiolite, which are mainly confined to fault zones. These zones include rocks with increased cracking, and deterioration and these are weaker in strength than rocks in the area around them.

In rocky slopes usually occurs the phenomenon of rock falls ie detachments and rock collapses from various heights and surfaces of slopes. Landslide phenomena also occur on steep slopes on which loose scree (slope deposits) and non-bonded superficial deposits are encountered.



1. Typical Landslide in clayey mélange of Geological Formation of Kathikas at Kathikas Area



2. Landslides in the area of "Petra tou Romiou" where the clayey formation of Kannaviou and Mamonia is underlain by hard chalks of Lefkara Formation



3. "Topple" Type Landslide in rockmass of Geological Formation of Pachna



4. Landslide occurring on rock mass of diabase sheeted dykes at Yerakies village

## Landslides due to human intervention

Human activities could cause landslides when they are not carried out with proper studying. In various development projects (residential development, roads, consolidations and other projects) for the construction of which man-made excavations – embankments-water supplies -irrigation, etc lead to changes in the natural regim of the area. Human activities are also inevitable in the mining and quarrying activities and may caused landslides in quarries or mining disposal material and generally on artificial slopes.



5. Instability on artificial slope at Ayious Vavatsinias village



6. Rural road at Kritou Marottou village which was affected from the adjacent landslide. The additional picture down on the corner shows in detail the toe of the landslide

## Landslides and built environment

In Cyprus landslides phenomena and other slope instabilities occur in hilly and mountainous areas, where the steep topography and the presence of weak and vulnerable lithological and geological conditions cause their appearance. The most important and probably more dangerous landslides for the built environment focused in mountainous and hilly areas of Paphos and Limassol district. Landslides in these areas are mainly related to the clay-bentonitic layers of kannaviou, Moni and Mamonia Formations and also Lower Marls of Lefkara Formation, marls of the Nicosia Formation and

clayey slope deposits as well.

Given the impact of landslides in conjunction with the damage from the earthquake some villages, such as Choletria, Ayios Photios, Statos, Fasoula, Phinikas, Korfi, Kivides and Pentalia have been abandoned and moved to safer areas after recommendations of Geological Survey Department (G.S.D).

Landslides cause often damages to houses, infrastructure projects such as roads, pipelines and networks of various services and agricultural facilities, often with serious cost.

Recently in Cyprus there is a huge residential development due to tourism and investment in real estate development. This development caused rapid changes in the environment. Especially in the Paphos district, construction of residential complexes is carried out obviously in areas with geotechnical problems such as swelling clays, loose and / or compressible soils and landslides. In these cases a detailed geological / geotechnical investigation is necessary to be carried out in order to avoid construction damages, primarily due to geological factors. Such problems arise from activation of old and dormant landslides or by the appearance of new landslides. The resulting economic cost to repair the building is too high, and the effectiveness of the solutions is often highly restricted.



7-8. Three year(3) evolutionary course of an active landslide at Pissouri village



## Factors, diagnosis and classification of landslides

The correct diagnosis by the Engineering Geologist of the causes and factors that cause a landslide is a prerequisite for effective treatment or its prevention. These factors are:

- The type of geological formations, as reported in detail in the beginning,
- The change of the inclination or the height of the slope as a result of human intervention,
- The presence of faults,
- Occasional strong earthquakes or local (artificial) explosions, eg quarries,
- The rapid change in concentration of underground water or and moisture content in the layers of the slope,
- The steep slopes and steep slopes created by its erosion by the rivers and streams,
- The development / percolation of surface water through cracks and weak zones of rocks, including seasonal springs,
- The winter rains that often appear as intense storm events and / or the effect of frost,
- The weathering,
- The change in vegetation,
- Excessive overload of the resistance of the slope by large / heavy construction.

The main features of landslide recognition are:

- The abnormal morphology of the surface of the slope eg reverse slope of the terraces to the inclination of the slope, the deviation from the vertical straight line of trees (eg cypresses or other trees with straight trunk),
- The presence of slopes with hemicircle or ellipsoid shape,
- The discontinuity of the layers of the strata,
- The change of the hydrographic network (rivers and valleys),
- The sudden appearance or disappearance of springs,
- The local vegetation in areas of weaknesses and surface irregularities,
- The cracking, displacement and, in general, disruption of roads and other infrastructure.

Based on field observations and measurements, landslides are classified into different types depending on the shape, depth, slope angle, number of slip surfaces, and the speed of the slip movement and the stage of their evolution.

## Remedial works

The main way to face these problems is the "prevention", namely to avoid disturbance of soil and water balance by the proper design of the project. Moreover they can be implemented monitoring and surveillance of existing landslides or landslide prone and / or geologically unstable areas using inclinometers. It is appropriate to avoid any serious construction work in geological sensitive / unstable regions, ie, potential landslides in the case that can not be safely stabilized.



9. Fissures and settlements on public/central road of Ayias Varvaras-Pentalias caused by the adjacent landslide

In cases where a landslide has occurred, the main measures to stabilize soil, based on the results of the necessary geological investigation are:

- The flattening of the slope,
- The reduction of the slope,
- The retaining of the toe of the slope by the construction of embankment,
- The development of surface drainage system,
- Execution "reliever" boreholes for demotion of water levels and, by this way, the hydrostatic pressure of groundwater,
- The development of dense vegetation with appropriate plant selection (including a net root system),
- The construction of suitable retaining walls,
- The anchor bolts,
- The construction of a pile-drilling system.



10. Stability measures-artificial slope construction-at the toe of the landslide (Pissouri village, photo 7 & 8)

## Research programs for the study of landslides

The Geological Survey Department in the framework of his research and studies and further more in cooperation with similar foreign agencies, prepared (both in paper and in digital form) preliminary hazard zonation maps with emphasis on the phenomena of landslides. These maps, which cover many mountainous and hilly villages of Paphos district and some of the Limassol district, are used by State Departments and Local Authorities, as a

tool for planning and building permits and generally for a more appropriate urban design.

The first landslide study was carried out by G.S.D. in collaboration with British Geological Survey during the period 1985 - 1986 at Paphos District, as the most vulnerable area of Cyprus in landslide phenomena. The areas of Kannaviou, Ayios Photios, Pentalia and Simou were included in this study.

Aiming at a comprehensive study of landslides in the Paphos district, G.S.D. carried out a two years research program (2008 - 2010) in collaboration with foreign experts (Scott Wilson Co). This study included identifying and mapping the various types of landslides and the compilation of map related to the geographical distribution of landslides, as well as the preparation of maps of Terrain Classification, Landslide Susceptibility and Landslide Indicative "Risk". These maps have (after the end of the program) elaborated by G.S.D. and geological suitability maps including zonation have been prepared based on the extent of risk / risk from landslides. These maps are very useful tool for any urban development. The study results will obviously help prevent catastrophic events by adopting appropriate stabilization measures or, where necessary, by prohibition of any development and construction and the creation of so called "white zones" where the soil - geological conditions are characterized as dangerous.

Basic work of this two-year program is the development of GIS landslide database / landslide Electronic Data Archive, which is open to complete / update with new data from landslides throughout the island.

Disclosure - disseminating the results of the study of Landslides in the Paphos district was on 22/10/2011 under the Pancyprian Seminar, held in Paphos, which was organized by the G.S.D. It was attended by more than 150 scientists (civil engineers, geologists, town planners, architects) from government departments, local authorities, the Technical Chamber of Cyprus and other scientific organisations.



11. Declaration of the works of the Pancyprian Seminar for the "Landslides of Paphos District" by the Minister of Agriculture, Natural Resources and the Environment Mr Sofoklis Aletraris