**University „Alexandru Ioan Cuza" of Iaşi**

**Faculty of Geography - Geology**

**Doctoral School of Chemical and Life Sciences and Earth**

# LANDSLIDES STUDY IN THE NORTH – EASTERN OF IASI

*SUMMARY OF PhD THESIS*

**Doctoral supervisor**
**Prof. univ. dr. Brânzilă Mihai**

**Doctorand**
**Purice Daniel-Andrei**

## INTRODUCTION

By extension, Iaşi is the legendary city of the seven hills. However, "this veritable natural amphitheater" in terms of a percentage of 50% of the total area occupied by the city, has to be placed in areas with high susceptibility to landslides.

Facing such risks, local authorities have conducted a series of consolidation works in several areas in the city, but due to the passage of time these structures began to deteriorate in the vicissitudes of time.

The various documents and geotechnical drilling carried out at that time revealed the main cause, the presence of water. With a seemingly homogeneous lithology, with frequent intercalations of silt and sand, colluvium mass chaotically arranged, the groundwater migrates vertically due to the rich supply from surface water infiltration. Following and of the degradations induced by human activity correlated with severe weather events lately, all these factors have started to put their mark on the integrity of the slope.

From this point of view, we believe that this thesis attempts to provide a clear picture of both the geological and Geotechnical instability phenomena highlighting the following:

- Geological aspects that are found on the eastern slope of the hill Copou.
- Estimation of local and general stability of the site
- Spatial report of the slip surface to bedrock.
- Estimation of the potential and probability of landslide occurrence and preparation of the hazard maps for the investigated area.

## Chapter I
## GEOGRAPHICAL FRAMEWORK

The Iasi county, is located in north-eastern Romania, in the central-eastern part of Moldavia, between parallels 46 ° 50 'and 47 ° 36' north latitude and between the meridians 26 ° 33 'and 28 ° 07 'east longitude.

### 1.1. Relief

The Iasi municipality and its surrounding area landscape are presented as a series of gentle hills, lined the left lane of Bahlui River and hills and plateaus belonging to the Coast of Iasi on the right of this corridor.

### 1.2. Climate

Iasi territory belongs to temperate continental climate zone with strong influences of the Azores maximum Baric during the summer and of the Eurasian cold period.

### 1.3. Hydrography and Hydrogeology

The hydric potential of Iasi is quite varied due to its location at the crossroads of two major morphological units: the Plain of Moldavia and Central Moldavian Plateau. Hydrogeological, Iași area overlays on the Moldavian Platform whose crystalline bedrock is covered by sedimentary deposits, with more than 1100 m thick. Throughout this the groundwater is free and captive, some even under pressure. Taking account of morphological and lithological conditions in this region, Maria Schram et al. (1977) defines four major hydrogeological units.

## Chapter II
## HISTORY OF RESEARCH

### 2.1. Geological, geotechnical and geomorphological research

The emergence of numerous publications on aspects of geological, geotechnical and geomorphological was possible due to diverse conditions in which the Iasi surroundings were formed. This paper summarizes some of the vast scientific collection,

dealing with aspects of "base" that the city has developed, despite the issues raised by the nature of the foundation soil.

### 2.2. International and national approach of landslides

**International.** The failure of a slope in the lake of Vajont Dam in Italy, which took place in October 1963 was one of the biggest disasters in the history of construction, when died about 2000 people.

**National.** Slope stability, considered through the main natural forms of manifestation of their failure, landslides, remains a constant concern for specialists in Romania.

### 2.3. Knowledge level of landslides in Iasi municipality area

In order to a uniform study slopes and consolidations carried out in all areas, at the level of Iaşi Municipality there is a successful attempt to divide the city slopes into 12 distinct zones according to the "Tracking time behavior of the consolidated slopes from the Iasi city "prepared by ICPROM Iasi in 1990.

## Chapter III
## REGIONAL GEOLOGY

From the geological point of view, the area is located on the major structural unit Moldavian Platform. Moldavian Platform is a typical platform on which the bedrock is covered by a thick sedimentary blanket of several thousand meters. Around blanket deposits outcrops only Cenomanian, Badenian, Sarmatian and Meotian.

### 3.1. Bedrock

Geological foundation was intercepted by several deep wells in the area, at a depth of 1120 m was thus shown that the base is composed of plagioclase paragneiss (with almandin and sillimanite or biotite and hornblende), grey coloured, with granoblastic structure, among which are intercalated leucocrate gneiss, widely crystallized, some of with pegmatoid structure.

### 3.2. Sedimentary blanket

In the sedimentary stack structure can be identified several cycles of sedimentation that covered structural surfaces formed in

the emersions periods when sediments have been deposited varying thickness. The literature confirms that the deposits that outcrops in Iasi territory belonging to Sarmatian stage, ie Basarabian undergrowth.

### 3.2.1. Bessarabian

Under Quaternary accumulations, from a depth of 12 m and up to 235 m, the drillings at Nicolina - Iaşi have intercepted deposits consisting of marl with fine sand, gray-blackish, sometimes schistous, with fine sands lens, gray-white, micaceous with thin intercalations of $CaCO_3$ (E. Liteanu et al., 1963).

### 3.2.2. Kersonian

The main area of extension of the Kersonian from the south of Iasi, P. Jeanrenaud (1961, 1965, 1971) separated the two "lithofacies": one marine-brackish and other coastal-deltas.

### 3.2.3. Recent formations

The newest deposits that occur in the area of Iasi and its surroundings are the terraces, with thicknesses ranging between 10 and 30 m, consisting of basal sands and gravels, clays and loess on top. To these are added the plain alluvium of Bahlui and those of its tributaries, but also clays and sandy clays deluvio-colluvial origin encountered, especially in the contact between at the edge of the plains and terraces of Bahlui or near the base of the slopes (N. Barbu et al., 1987).

## Chapter IV
## ASPECTS REGARDING LANDSLIDES OCCURRENCE

### 4.1. General information

Landslides fall, along with earthquakes and floods, among the natural disasters that cause loss of life and significant property damage.

### 4.2. Causes and actions which determine landslide occurrence

The landslides are a result of the disturbance of the state of dynamic equilibrium in which the slopes, balance maintained on

the one hand by the environmental factors (active forces), and on the other hand, massive opposition to this action (resistive forces ). If the resistive forces exceed the active ones, the slope movement is accelerated to achieve a new state of relative equilibrium.

Stanciu and Lungu, 2006, groups the two types of actions in permanent actions and temporary actions (long-term, respectively short-term).

## Chapter V
## ASPECTS REGARDING SLOPE STABILITY, WITH INDIVIDUALIZATION TO EASTERN SLOPE OF COPOU HILL

### 5.1. Site

The area treated in this paper is located in the north - east of Iași, with a total area of about 241 ha and a maximum level difference of about 88.00 m, between the maximum altitude of 135.00 m in the right street Sararie, to the intersection with Stefan cel Mare si Sfant street, respectively the minimum altitude of 46.50 m in the right of C.A. Rosetti Boulevard.

### 5.2. Checking the general and local stability

The verification of general and local stability of the slope areas of the Eastern Copou area was performed using GEO5 program. The calculation method used is Fellenius / Petterson, having a circular failure surface.

### 5.3. Working methodology

The safety coefficients slope failure in the natural conditions, with the actual loads, is comprised between 1,01 (for profile 3-3') and 2,20 (for profile 1-1'). The national technical standards consider a slope as stable when the admitted minimum safety coefficient $Fs_{adm}$ greater than 1,30.

For the pairs of plans 3-4, 5-6 and 8-9, due to the reduced distance between lithological cross sections of each plan, we extracted relative levels of the probable slip surface in order to conduct a special report of its to the bedrock (marl). The 3D

modeling of the three structures - probable sliding surface, groundwater and bedrock - we were allowed to create a clear picture of the spatial reporting of the sliding surface to the groundwater and marl clay.

## Chapter VI
## LANDSLIDE RISK ASSESMENT

Knowing the potential and probability of failure of the slopes is helpful to develop strategies for improvement, protection and sustainable utilization of the sites. Natural risk maps for landslides represents the synthesis of the equilibrium state forecast data relating the slopes, damage to property and losses of human lives that may be caused by instability phenomena producing on a certain area in a given time.

### 6.1. Estimation of the potential and probability of landslide occurrence, with individualizations to eastern slope of Copou Hill

On a slope, the change of state of efforts is the result of the simultaneous action of natural and artificial factors. The evolution of these conditions should be identified, monitored and extrapolated over a period of time sufficient to take effective measures to avoid or minimize the possible disasters that could be caused by landslides. By developing the hazard maps at landslide in this area want to bring scientific support both local authority in the field of spatial planning and Urbanism and County Department of Culture, Cults and National Cultural Heritage. In drawing up the risk map in terms of the potential for landslides we adopted the working methodology according to the "*Guidance for drafting risk maps at slope failure for constructions stability*" (GT 019-1998).

### 6.2. Working methodology

In order to achieve slip susceptibility map for the eastern slope of the hill area Copou the main data sets were processed using ArcGIS software and AutoCAD Map 3D. After preparing each thematic maps corresponding to the 8 parameters (Ka…Kh),

we used the *Weighted Overlay* option of those factors in order to obtain the hazard map at landslide (***average factor map Km***). The resulting product will include a dense mosaic of polygons defined by very different Km values (theoretical value between 0 and 1). The final map Km will synthesize this extreme variability into strips summary value.

### 6.1.1. Thematic maps

1. **Lithological criteria – Ka = 0.80.**
2. **Geomorphological criteria – Kb = 0,30÷1,00**
3. **Structural criteria – Kc = 0,10**
4. **Hydrological and climatic criteria – Kd = 0,40**
5. **Hydrogeological criteria – Ke = 0,30÷0,80**
6. **Seismic criteria – Kf = 0,90**
7. **Forest criteria – Kg = 0,20÷0,80**
8. **Anthropogenic criteria – Kh = 0,20÷0,80**

### 6.2.1. The average risk factor Km

Analyzing the probability hazard map at landslide, we note that the eastern slope of the hill Copou has values only in two of them, namely:

- **0,31÷0,50 (medium to high probability)**, for **Km=0,40**, respectively **0,50**
- **0,51÷0,80 (high probability)**, for **Km=0,60**, respectively **0,70**

For the field medium-high probability (0.31 ÷ 0.50), the coefficient Km was generated in an area of 107. 4 ha (44.59% of the total). Areas with high probability of landslides occupy 133.46 ha (55.41%), polygons related to this criteria being distributed in areas where building density is high.

Analyzing the calculated stability factor, with the probable location of the detachment points and landslide hazard maps, we see that areas with values of the stability factor less than the admitted safety factor ($Fs_{adm}$) overlap with the polygons characterized by the field with high probability producing landslides.

In conclusion, from the analysis of the hazard map Km, we can say that for the eastern slope of the hill there is a high probability for triggering landslides, the affected area percentage being around 55%. These areas coincide with the areas in which the action of anthropogenic factor is high, but also in the areas where the slope is steeper than 15%.

## CONCLUSIONS

Through this paper, we achieved slope failure risk evaluation and assessment to the eastern side of the hill Copou through a complex analysis based on theoretical background, but also practical.

The groundwater is the main triggering factor for landslides. Colluvial slope becomes unstable by soaking soils on the slopes with large amounts of water which reduces shear strength parameters of the soil.

Once identified the possible slip surface, we have extracted the information regarding the main geometry (depth and length), based on which we made the spatial reporting block diagram of the slip surface to the groundwater and the bedrock (marl). These 3D graphics render the areas where the lower limit of slipping surface falls below the top of the marl, considered the bedrock of the site due to geotechnical characteristics much better.

According to the criteria described in GT 019-1998, we prepared the thematic maps for each parameter (Ka…Kh), assigning specific values of the existing situation, using the ArcMap, part of ArcGIS program. How current regulations contained in GT 019-1998 do not permit highlights of detail, only the general details about the study area, multiple values of several criteria (Kb, Ke, Kg, Kh) were quantified and values were assigned according to the assessment scale described in option Weight Overlay.

Safety factor values computed for the 10 plans described in Chapter 5, and the average risk coefficient Km map, highlight the

"critical" areas where the safety coefficient is less than the one allowed by the technical regulations in force (STAS 2914 - 1984).

After completion of the Km hazard map we can conclude that at the level of the eastern slope of the Copou hill there is a high probability of landslide occurrence, the share of the affected area being of approximately 55%. These areas coincide with the areas in which the action of anthropogenic factor is high, and the area in which the slope is steeper than 15%.

**Contributions**

- By plotting of a 10 cross lithological profile and on the information of the 26 Geotechnical, we estimated the value of the safety factor for different areas in the study area.
- We have achieved three-dimensional graphics based on which we highlighted spatial reporting of the sliding surface to bedrock and groundwater, highlighting the degree of degradation of marls and direct implications for the frequency of instability.
- By preparing the thematic maps according to the criteria described in the Guidelines for drafting risk maps of slip stability of slopes for construction (GT 019-1998), resulting in final map of average risk coefficient Km, we managed to estimate the probability of landslides with a focus on the eastern slope of the hill Copou.

Based on of slip hazard map obtained there can be developed new intervention plans for the rehabilitation of the area in order to reduce landslide risk. Based on the average coefficient values of slip hazard, there can be reduced the surface area of investigation resulting the possibility of a good concentration of the resources in order to anticipate the probable slip surface depth.

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