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J-CROSS

CENTER FOR DEVELOPMENT OF PELAGONIJA REGION

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STUDY ON LANDSLIDES MAPPING AS A RESULT OF FLOODS IN THE PELAGONIA REGION

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Abstract

This study is part of the project Joint Cross Border Cooperation for Securing Societies against Natural and Man-Made Disasters (J-CROSS) funded by Interreg IPA Cross-border Cooperation Programme "Greece - Republic of North Macedonia 2014-2020."

J-CROSS project is the result of long-standing cooperation between the Region of Western Macedonia, Greece and the Pelagonija Region, Republic of North Macedonia. Both regions are fully aware of the need to secure development initiatives and opportunities, against risks from natural and human-made disasters. The area of Western Balkans is in the epicentre of many development programmes derived from organizations such as the European Union, World Bank, European Investment Bank and others. Big infrastructure projects are planned in the broader area, including transportation (road and rail) networks, natural gas pipelines and logistic centres. The previous years both regions established close cooperation through projects in the fields of economy, environment and social cohesion.

Both regions acknowledged the importance of civil protection in securing big infrastructure projects and investments. Climate change increases the risk from natural hazards, while big infrastructure projects (such as TAP pipeline already under construction) increase the risks of a human-made - human-induced disasters. Refugees' flows also put high pressures to cross border area, being a civil protection priority, as proved by the invitation of Joint European Civil Protection Mechanism to support humanitarian operation in the two countries' border area. Therefore, J-CROSS tackles the challenge to minimize increasing -by climate change- frequency and severity of risks in both regions by jointly planned, developed and implemented practical actions.

The overall J-CROSS objective is to minimize the risks from natural and human-made disasters for the regions of Western Macedonia & Pelagonija in a long-term basis and in a way that can be replicated in other cross border areas, while the purpose of this study is to identify risk landslides

1. Introduction

The study for landslides as a result of the floods in the Pelagonia region is based on available data on the natural factor, historical data on floods and landslide events, landslide and flood data analysis from our own databases, and others sources. The study is designed to highlight the problem of landslides and floods in the region and to propose future steps to reduce the potential damage from these natural hazards.

Specifically, data from the following available technical documentation were used in the preparation of the Study:

- Center for development of Pelagonia planning region: web site http://investinpelagoniaregion.mk/pelagoniski-planski-region/opsti-karakteristiki/
- Draft Strategic Environmental Assessment for the Draft Regional Waste Management Plan for Pelagonia Region (07/10/2016) EuropeAid / 136347 / IH / SER / MK
- Study on the geo-diversity and geo-heritage of the R. of North Macedonia and other components of nature (biodiversity and landscape diversity) Skopje, 2016
- Basic Geological Map (BGM) of the Republic of North Macedonia on a scale of 1: 100000, sheets Krusevo K34-91, Ohrid K34-102, Bitola K34-103, Vitolishte K34-104, Lerin K34-115
- Pelagonia Water Management, Bitola Field, Condition, Development and Perspective, Bitola (1998), authors: B.Sc. Civil Eng. Miloshevski Metodija and B.Sc. Civil Eng. Zlateski Vladimir
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- HMS Strezhevo - Bitola. Main supply channel. Technical report on the engineering-geological characteristics of the rock masses along the main supply channel km.0 + 000-44 + 078. May, 1983. Author: Borce Andreevski B.Sc. Eng., Responsible Designer at HMS Strezevo

- Elaborates from geotechnical investigations on a number of landslides along the alimentary and main water supply channel of HMS Strezevo. Faculty of Civil Engineering, 2015
- Elaborate from geotechnical investigations for repair of instability (landslide) on the regional road R1107, Prilep (Lagovo) - Mariovo, position km. 35 + 000.00, Geing Krebs und Kiefer, Skopje, 2015
- Elaborate from geotechnical investigations and laboratory investigations on landslide on position 13 + 300 on the main supply channel of Hydro-system Strezhevo, intake construction G0 and water supply pipeline to REK Bitola with technological water from the accumulation Strezhevo, DGR Geotehnika Nova, 2017
- Project research program and development of a technical solution for the repair of a potentially unstable zone on the road R1311, Bitola - Novaci at km 1 + 900, Faculty of Civil Engineering, Skopje, 2015
- Landslide information on the M5 motorway on the Resen Bitola section and necessary repair measures, Faculty of Civil Engineering, Skopje, 2010
- Basic design for repair of the local road Gneotino-Brod from the exit of the village Gneotino to the crossroads on the way to St. Stefan-Municipality of Novaci: EKO-MAR Bitola, 2015
- Basic design for repair of landslide on regional road R2331 Bitola-Nizhe Pole: Geing Krebs und Kiefer
- Project program for preparation of Technical solution for landslide repair on the road R-507 from village Magarevo to the children's resort (Pelister), 2011
- "Landslide Early Warning System: toolbox and general concepts". E. Intrieri, G. Gigli, N. Casagli, and F. Nadim. Nat. Hazards Earth Syst. Sci., 13, 85–90, 2013 www.nat-hazards-earth-syst-sci.net/13/85/2013/ doi: 10.5194 / nhess-13-85-2013
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2. General features of Pelagonia planning region[1]

Pelagonia planning region is located in the southwestern part of the Republic of North Macedonia. It covers the basins of the Pelagonija and Prespa valley and covers an area of 4717 km^2 or 18.9% of the territory of the Republic of North Macedonia. The name of the area is Pelagonia valley which occupies most of the territory of the entire planning region. Pelagonia occupies the central-western part of the Republic of North Macedonia. It is composed of the Bitola and Prilep fields in the Republic of North Macedonia in the basin of the Black River and its tributaries and the Lerin Field in the Republic of Greece. The valley is surrounded by the Baba Mountains, Busheva Mountain to the west, Dautica and Babuna Mountain to the north, Selecka Mountain and Nidze to the east, while to the south and southwest it is surrounded by the slopes of Neradska Mountain which is located in the Republic of Greece. The average altitude ranges between 540 and 610 meters in the Bitola field and 615 and 710 meters in the Prilep field.

The hydrological potential in the Pelagonia planning region consists of the Black River with tributaries Blato, Shemnica, Dragor and Eleska River. The Black River catchment is part of the Aegean catchment area. Black River is the main and largest river flow in the Pelagonia planning region. The total length is 207 km and the whole course is in the Republic of North Macedonia. The catchment area of Black River is 5,890 km^2 which represents 28.68% of the catchment area of the river Vardar into which it flows. During the estuary, Black River has an average outflow of 37 m^3 / sec. Lake Prespa is a special natural and geographical tourist motive and destination for the development of lake tourism in this region.

Important for irrigation of arable land in the region are the artificial accumulations of Strezhevo and Lake Prilep, as well as the artificial accumulation of Suvodol.

Pelagonia region has 276.777 ha of agricultural land. Out of this 117.770 ha is arable land and the remaining 159.007 ha - pastures. In the structure of arable land - plots and gardens account for 83%. As an industry, agriculture accounts for 4% of production and 5% of total employment in the region. The total forest area in 2014 is 143.545 ha or 14.6% of the total forests in the country.

In relation to toe ore deposits in the region, with the most important economic significance are the coal (lignite) deposits in Pelagonia and Mariovo, which are currently used in the three REK Bitola blocks and the non-metallic deposits of diatomaceous earth in the Monastery - Mariovo and the white marbles in Prilep. A special mineral resource are the cold mineral springs near the village Medzitlija, Bitola, which have been exploited for a long period of time.

The exchange of goods and people with the neighboring countries is realized through the Stenje / Gorica road border crossings at Resen with the Republic of Albania, and Medzitlija / Niki at Bitola with the Republic of Greece.

There is also a railway crossing near the village of Kremenica with the Republic of Greece, which is currently not in use.

[1] (most of the data is downloaded from the website http://investinpelagoniaregion.mk/pelagoniski-planski-region/opsti-karakteristiki/)

There are two national parks on the territory of Pelagonia planning region. Pelister National Park and part of the Galichica National Park which represent huge potential for tourism development and improvement of the economy in the region.

The territory of Pelagonija planning region is administratively divided into 9 Municipalities: Bitola, Prilep, Resen, Dolneni, Krushevo, Demir Hisar, Mogila, Krivogashtani, Novaci (Fig. 1).

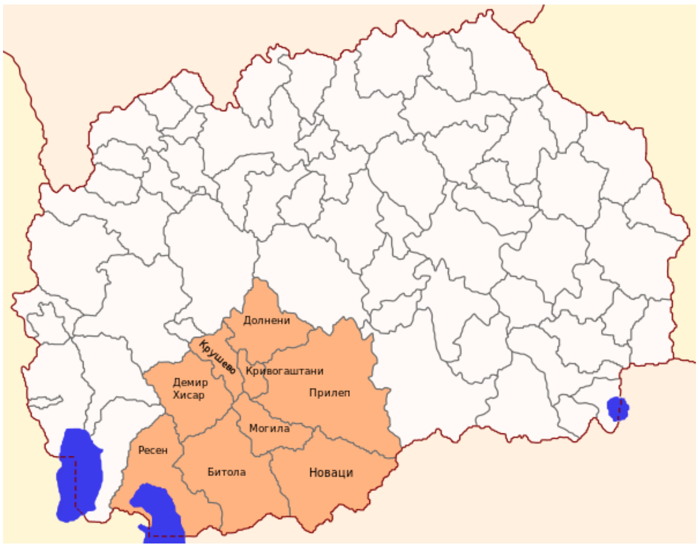

Figure 1. Position of Pelagonia planning region in the Republic of North Macedonia and municipalities in the region

3. An overview of natural factors

3.1. Geology[2]

Pelagonia Valley occupies most of the territory of the entire Pelagonia region. The valley is composed of the Bitola and Prilep Fields in the Republic of North Macedonia in the Black River basin and its tributaries and the Lerin Field in Greece. The valley is surrounded by the mountains Baba, Busheva Mountain to the west, Dautica and Babuna Mountain to the north, Selecka Mountain and Nidze to the east, while to the south and southwest it is surrounded by the slopes of Neradska Mountain in Greece. In the past during the Tertiary period, Pelagonia was lake and therefore today there is a high prevalence of humus and alluvial soils (especially in the Bitola Field). The average altitude ranges from 540 to 610 meters above sea level in the Bitola field and 615 to 710 meters above sea level in the Prilep field. The region is represented with the Pelagonia horst anticlinorium which is characterized by specific lithological composition, tectonic structure and degree of metamorphism.

According to the Basic Geological Map of the Republic of North Macedonia, arranged by age, the following significant lithological units are represented (see also Figure 2):

Precambrian rocks

Muscovite gneisses (Gm): They are found in the lower parts of the Babuna River syncline. They are gray in color, their structure is lepidogranoblastic. The minerals in these rocks are quartz, K-feldspar, plagioclase and muscovite, with biotite, garnet, epidote and titanite as minor constituents.

Double-mica gneisses (Gmb): these rocks represent magmatic gneisses enriched with K-feldspars during the protruding of granite rocks in the Pelagonia massif. They are pale, with medium to large grains, of lepidoblastic structure and a slaby texture. The main minerals are quartz, K feldspar, plagioclase, biotite and muscovite , with garnet, epidote and titanium appearing as secondary minerals.

Micaschists (Sm): this unit represents the micaschists masses where granitic-graphitic micaschists, graphitic quartz micaschists and distene micaschists occur. The granitic graphitic micaschists are black gray with a slaby texture and granular structure. They consist of quartz, muscovite, garnet, graphite, and epidote, with albite, chlorite, rutile, magnetite and titanium as secondary. The distene micaschists are characterized bycoarse-grained, gray and distene crystals up to 10 cm long. They are composed of quartz, muscovite, disten and garnet, and the secondary minerals are titanium, epidote and chlorite.

Granite micaschists (Smg): They have a grayish yellow color with a folded texture and granular structure. From the minerals they include quartz, muscovite and garnet, less epidote and chlorite, and at certain localities occur side by side: biotite, feldspar, rutile, amphibole, titanium, tourmaline and magnetite.

[2] The data are mostly taken from the KGC Map of the Republic of North Macedonia

Marble series (M): above the rocks of the gneiss-micaschists series, in the eastern flank of Pelagonia, the marble series lies concordantly with thickness of about 2,000 meters. The rocks in this series are mostly covered by Cambrian, Cretaceous and Tertiary-Quaternary creations, and are partially discovered only on the Nidze-Labinica-Melnica-Veprcani-Belovodica route. Along the exposed contact of the gneiss- micaschists with the marble series along the entire stretch a horizon of 5-50 meters thick of cipolines is developed, and in the area of Nidze top, where this transitional horizon is thicker, the micaschists are changed. Such a transition and a concordant position indicate a gradual relationship between these two series. On the basis of the mineralogical composition of the marble series, two main lithological members are distinguished: dolomite and calcite marbles, among which there is a gradual transition.

Granodiorites (δγ): these magmatic rocks occupy a very small area and have been discovered with only a few small lenses. They represent large-grained rocks with pink or white microcline and albite granules, with dimensions of 5 cm. They have a massive to slab texture and a porphyroid structure. They consist of: quartz, K-feldspar, plagioclase and biotite as major minerals and by-products: muscovite, epidote, chlorite, zircon, titanium and magnetite.

Paleozoic

Graphitic schist (Sgr): these schists are local facies of quartz-sericite schists and are observed in the upper reaches of the Brajcinska River. They appear in the form of lenses with a thickness of several to ten meters and a length of more than 1 km. They are dark gray to black with a shale texture and lepidogranoblastic structure. They consist of quartz, graphite and sericite.

Green schist (Sco): Appear on the northwest and western slopes of Mount Baba as large masses of green schist and are dominant over other schist. Their relation to other schist is of tectonic origin.

Phyllite, agrilochists, agrilophilites and siltstone (Sgse): phyllites are gray, greyish-brown with a shale texture and a lepidoblast structure, they are quite crumbly and leafy. They are constructed of sericite shells and fine quartz grains. As accessory minerals appear chlorite, muscovite, epidote, graphite, limonite and titanium. Agrilochists are gray, gray-black or brown shale rocks consisting of sericite and limonite, with rare quartz grains. The metasandstones are gray, dark gray or yellowish shale rocks composed of round or slightly elongated quartz grains with limonite or sericitic limonite material.

Metamorphic diabases (ββ): they are dark green schist rocks consisting of kaolinized and sosiritized plagioclases, actinolite, chlorite, epidote, sericite, coisite and magnetite. Quartz appears as a regular mineral. It can be noticed that the most metamorphosed are the peripheral parts of the masses.

Metamorphic conglomerates and sandstones, phyllite etc. (Sq): These facies consist of metamorphic conglomerates and sandstones, phyllites, green slates and cornices. Metaconglomerates appear as basal to this series and as intrastratified in multiple horizons of phyllitic schists. The largest masses appear just below the marble limestones. The metasandstones are gray-green rocks of slate texture, composed of quartz grains, sericite and biotite. Phyllites and phyllitic schists are the basis on which all other lithological members are intercalated. They are greenish-brown in color and have a lepidogranoblastic texture, consisting of sericite and quartz.

Granite (γ): Granite is widespread on Pelister and forms the magmatic core of Baba Mountain, extending partly north to the Black River. They intruded concordantly in the Paleozoic shale. They can be divided into two types: alkaline granites and adamelites. The granite is light gray to white, with a prominent presence of quartz and feldspars.

Mesozoic

Conglomerates (T_1) metamorphic quartz conglomerates appear in the base of other Triassic members. They consist of pieces of quartz, quartzite, various shales, and lie transgressively over older phylloides and quartzites.

Laminated and massive limestones ($T_{2,3}$): Laminated limestones are not very often and lie either above metamorphic quartz conglomerates or directly through Paleozoic shales. They have light gray, gray or dark gray color. Above them are massive limestones with gray, gray-white, blue to gray-red color, and with marked karstification.

Top sediments (K^2_2): Turonian sediments are about 2000 m thick and are spatially divided into two zones. Generally, after all these sediments are distributed, they also exhibit features of a clastic series, in which, according to the presence of certain lithological members, three phases are formed:

- Conglomerates and sandstones
- Sandstones, agriloschists, clayey shales and conglomerates
- plated and massive limestone.

Cretaceoussediments (K^3_2): The senon sediments are about 1700 m thick and appear in zones of north-south extension. Based on the lithological characteristics and facies of the sediments and their position, several facial levels are distinguished:

- Conglomerates and sandstones
- Sandstones, clays and conglomerates
- Sandstones, alevrolites, clays and limestones (flysh)
- platy and banked limestone.

Cenozoic

Pliocene (Pl): Pliocene sediments are represented by frequent shifts of gray to silty sandstones, yellow fine-grained sands, gray-white marls and green clays. White and yellowish limestones are present in the highest parts. Gray sandstones are poorly represented and stratified in banks of 0.5 to 2 m thick. They are usually coarse-grained and conglomerate-like. The grains are made of quartz, limestone and rounded small pieces of different rocks cemented with carbon clay.

Quaternary

Glacial-river sediments (fgl): appear at the base of Mount Baba as a halo of several kilometers. They are made of marine material: granite blocks, granodiorites, gabbros and various schists. The material is very decomposed and the blocks are poorly cemented with the same decomposed material.

Deluvium (d): Deluvial sediments are poorly developed and are represented by unprocessed angular pieces of gneiss, amphibolite and quartz fragments, poorly associated with red limestone-sandy deluvial clays. Their thickness ranges from 2 to over 5 m.

Proluvium (pr): Proluvium is widespread and forms a halo around each hill, especially around the hills of the ednge and in the Pelagonia valley itself. The thickness is variable and ranges from 5 to 10 m. They are composed of loamy sand with occasional partially processed pieces of rock that consist the surrounding terrain.

Alluvium (s): Alluvial sediments are distributed along the riverbeds of all major rivers but are most prevalent in the Pelagonija valley, where all rivers deposit transported sediment. These processes produce very thick alluvial sediments. These sediments are represented by alternating alteration of loamy and sandy material, which is precisely determined as sandy and alevrite clay.

3.2. Seismic characteristics

From the seismic and tectonic aspect, the Pelagonia planning region (Figure 3) belongs to the so-called Pelagonia seismic zone. Based on current seismological research and macro-seismic regionalization of the Republic of North Macedonia, the expected maximum earthquakes in the region from local or remote hotspots are with epicenter intensity up to VII degrees according to the MKS scale.

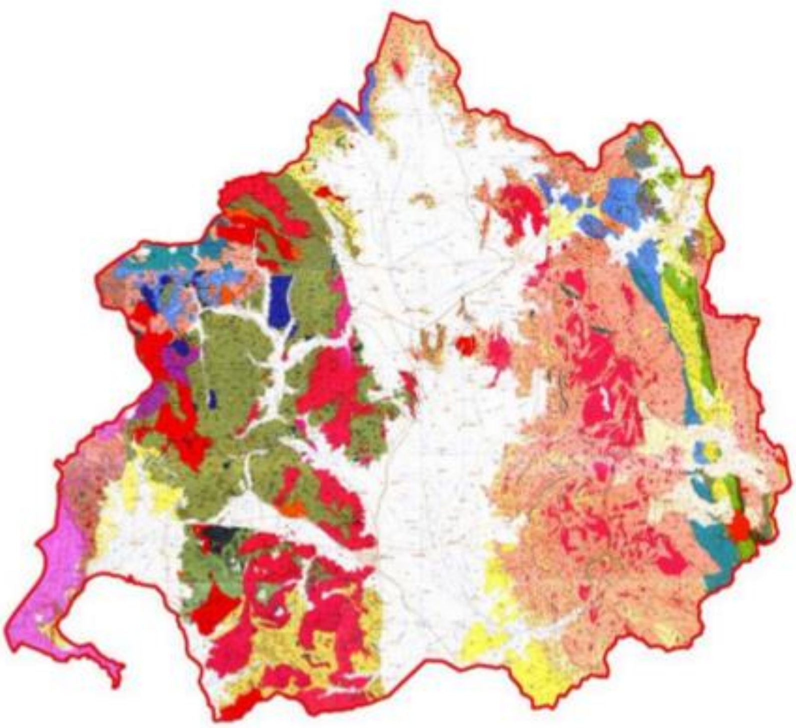

Figure 2. Geological map of Pelagonia region, excerpt from BGM 1:1000000[3]

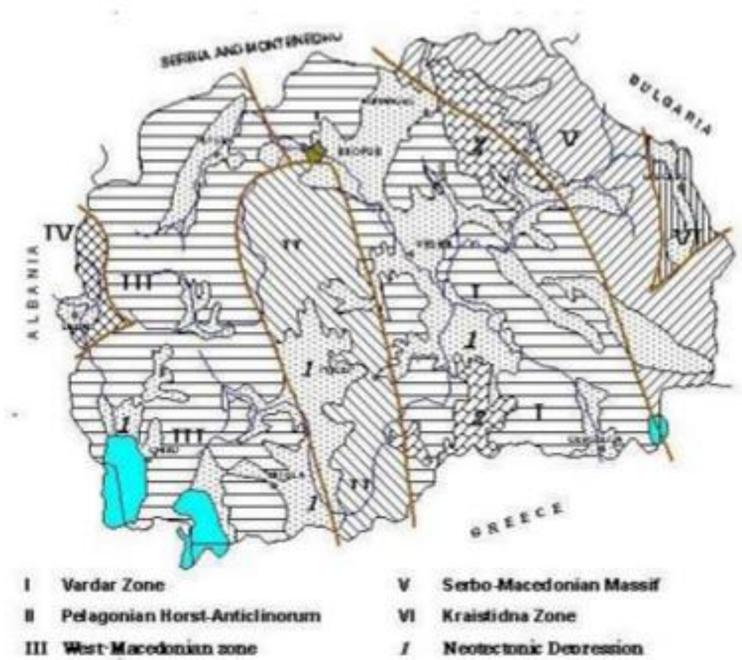

Figure 3. Tectonic zones in the Republic of North Macedonia

3.3. Geomorphology

The Pelagonia Valley is the largest valley in the Republic of North Macedonia and covers an area of 3682 km^2. On all sides it is surrounded by medium height and high mountains: Baba (Pelister, 2601 m) and Busheva Mountain (Musica, 1791 m) to the west, Mokra massif (Solunska Glava, 2540 m) with Dautica from the northwest, Babuna (Kozjak, 1746 m) to the northeast, Selecka Mountain with Dren (Livada, 1664 m) and Nidze (Kaimakchalan, 2520 m) to the east, and to the south and southwest (on the territory of Greece) by the slopes of the Neradska Mountain.

The valley was formed by radial tectonic movements (displacement) between the middle Miocene and the Quaternary. In the Pliocene the valley was overlain by the large Pelagonia Lake, from which thick sediment deposits on the lake bottom remained. Pelagonia is divided into northern (Prilep) and southern (Bitola) parts with more hilly elevations in a parallel direction (Topolchanska beam). The plain at the bottom is from 650 m asl in the north to 570 m asl in the south. Black River flows through Pelagonia with tributaries: Blato, Shemnica, Dragor and Eleska (Sakuleva) River. The entire hydrographic network forms part of the Black River basin.

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[3] http://www.moepp.gov.mk/wp-content/uploads/2016/12/STUDIJA_PRIRODA.pdf

Among the mountain massifs present in the Pelagonia planning region, Baba with Pelister with Pelister peak 2601 m and Nidze Mountain with Kajmakchalan peak 2520 m should be highlighted.
They are among the mountain ranges characterized as high mountains with altitude above 2000 m. Galicica has the most important peak Magaro 2254 m, followed by the Ilinska, Plakenska and Bigla massif with Stalev Kamen peak 1998 m. In massifs with medium mountain relief where the absolute height is greater than 1000 m are the mountain ranges of Buseva Mountain with Musica peak 1788 m, peak Flat 1653 m.
Among the listed mountain massifs as macro-relief spatial units are valley basins with a large number of fields, areas and terrains. Given the timing and conditions of their formation, the following are distinguished: typical valleys (areas bounded by watersheds that intersect river flows at the most suitable sites in canyons); erosive river extensions; tectonic trenches and fields. They have different territorial distribution, size and altitude. The valleys are mainly scattered along the composite valleys of the rivers.
An overview of the valley sections that are important for this region is shown in the following Table 1.

Table 1. Overview of valley's spatial units in the Republic of North Macedonia by height and terrain types (source: Markoski B. 1992)

Valley	Relative altitude of the valley m	Relative altitude of the plains	Plains km^2	Hilly relief km^2	Mountain relief km^2	Total area km^2
Mariovska Valley	350-2520	/	/	51,6	845,7	897,3
Ohrid-strushka V.	575-2300	600-800	204,9	192,3	932,1	1318,3
Kishevska V.	500-2200	500-600	97,6	177,7	598,9	874,2
Bitola Field	500-2601	500-700	686,9	621,8	184,0	1492,7
Prilep Field	575-2100	575-700	633,9	208,9	101,0	943,8
Demir-Hisar V.	600-2000	600-700	66,8	211,5	367,0	645,3

Prespanska V.	850-2500	850-1000	194,6	/	364,2	558,8

Along the Black River valley are Demir Hisar Valley (upper catchment area of Black River to the village of Buchin), Pelagonija with Prilep Field (northern part of Pelagonia Valley to Topolchanska beam) and Bitola Field (central part of Pelagonija valley between Topolchanska beam to Skocivir and the state border with Greece) and Mariovska valley (immediate basin of the Black River from Skocivir to 388 m near Varelova Tumba).
The Prespa Valley (Prespa Lake Watershed) is distinguished as a separate valley area.

3.3. Climate

The region is dominated by a temperate-continental climate with large climatic influences from the north that cause the climate to resemble as continental during the winter. The annual amount of rainfall ranges from 570 mm in the Prilep region, 643 mm in the Bitola region, 915 mm in the Krushevo region, while the Demir Hisar area is characterized by 737 mm. It should be emphasized that in terms of temperature there are large temperature oscillations during one year. Summer temperatures reach up to + 40 °C, while the minimum in winter reaches -30 ° C, and the average annual temperature is around 10 °C.

In the Prespa region the climate is characterized by cool summers and not very cold winters, a fact that is due to the proximity of Prespa and Ohrid lakes. In the high mountains, the climate is mountainous, i.e. there are cold winters and cold summers, with precipitation around 1000 mm in the form of snow during the winter. Snow is often present and runs from November to May. Pelagonia Valley is also characterized by the presence of frost, both in the mornings and in the afternoon, from September to May or dew in the warmer days mainly from March to November.

An overview of some climatic parameters can be seen in Figures 4 and 5.

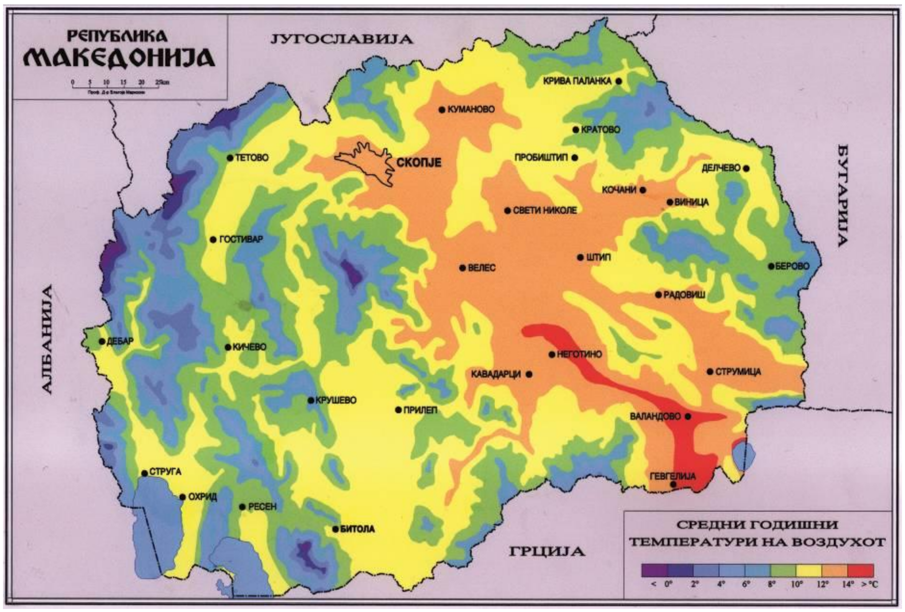

Figure 4. Average annual air temperatures (Lazarevski, 1993)

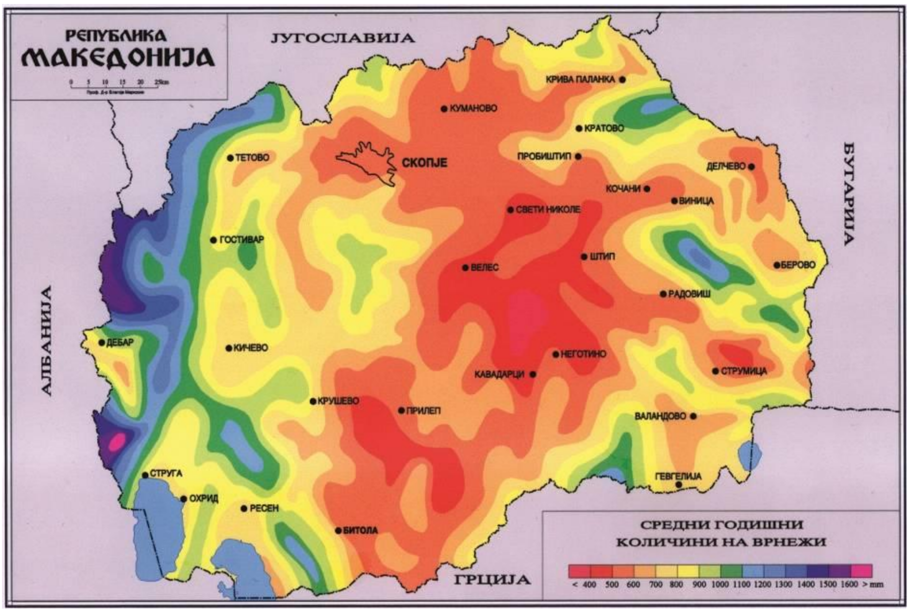

Figure 5. Average annual rainfall quantities in the Republic of North Macedonia (Lazarevski, 1993)

For landslides, precipitation is certainly the most important, especially the occurrence of intense rainfall. Although such data can be found in a large number of studies, unfortunately, so far, no correlation has been established between the intensity and occurrence of landslides (threshold of intensive precipitation that causes landslides). This is a scientific challenge that should be given greater attention in the future.

4. Generally for landslides as a natural hazard and their zoning

Landslides are defined as instabilities in the terrain, characterized by the movement of rock masses along natural or artificial slopes.

The construction of individual buildings or large construction sites in terrain possessing naturally unfavorable morphological, hydrological, geological, geotechnical and other conditions (which also applies to certain parts of the Pelagonia planning region), contributes to the development of instability and causes significant socio-economic damages, and, in exceptional cases, even the loss of human life.

The worst landslides in human history have been caused by a unfortunate combination of natural conditions and construction activity. Extreme examples are the 1920 landslides in China when more than 30,000 people died; Sichuan 2008, also in China, where the earthquake caused a large number of landslides that blocked 256 rivers, and one third of the more than 80,000 thousands of casualties were due to slides. In the scientific and professional literature, there have been thousands of cases around the world of completely or partially buried towns and villages, collapsed dams, roads, viaducts. Due to the accelerated global development and often inadequate infrastructure planning, these phenomena will be even more relevant in the future.

The economic damages of landslides include direct and indirect losses on both private and public property. Direct costs are defined as the cost of replacement, rebuilding, repair, or maintenance due to landslide damage or destruction of property or installations, Schuster R.L. and Fleming R.W. (1986), Schuster R.L., (1996).

All other losses are defined as indirect: depreciated property in landslide-affected areas, loss of property tax due to depreciated property, loss of industrial, agricultural, forestry production, reduced tourist income as a result of damage to tourist facilities or interruption of traffic systems, loss of production from domestic animals due to their death, injury or psychological trauma, costs due to measures taken to prevent or reduce the potential to trigger activation of landslides etc.

In the case of the Pelagonia planning region, it can be freely stated that landslide damages can for the most part be defined as indirect.

Due to the complex geological-tectonic, geomorphological, climatic and other conditions, parts of the territory of the Republic of North Macedonia (and Pelagonia planning region) fall into the category of terrain with natural predispositions for development of instability. So far, a large number of landslides have been registered which have directly or indirectly endangered the infrastructure in the region.

The economic losses from these adverse events are estimated at hundreds of millions of euros. In addition to the damage to existing infrastructure, additional costs also arise from the need to design and execute large-scale construction works: construction of new individual and collective residential buildings or whole neighborhoods, utilities, road and rail repair, support structures, anchorage constructions, installation of road slope protection nets, drainage systems and other repair measures. The constant and necessary monitoring of unstable phenomena also entails "permanent" costs. A typical example of greater economic damage may be the landslide in the zone of the Strezevo hydro system supply channel, which carries a water to the REK Bitola, which is designated as "G-0".

In order to prevent and avoid such socio-economic losses, worldwide practice and trend is the preparation of inventories and maps of susceptibility, hazard and risk of landslides. Proper use and interpretation of these maps creates the opportunity to assess future instability, improve the work of protection and rescue services, take timely preventive measures and ultimately define areas in which infrastructure should not be developed. The following are the basic definitions of terms used in this field of engineering:

Basic definitions of terminology that are common for zoning the susceptibility, hazard, and risk of unstable occurrences are the following:

- **inventory (cadastre) of landslides**. Cadastre of location, classification, size, activity, date of occurrence and other features of landslides in one area.
- **landslide susceptibility ing**. Quantitative or qualitative assessment of the classification, volume (or size), spatial distribution of landslides that exist or could potentially occur in a particular area. Susceptibility can also be included in the description of the speed and intensity of existing or potential slides. Susceptibility to landslide includes landslides that have their source in or outside the development area but can move in it.
- **landslide hazard**. A state with the potential to cause unintended consequences. The description of the hazard of sliding may include the location, size (volume), classification and speed of potential landslides and any resulting breakage material, as well as the likelihood of their occurrence within a given time frame.
- **elements at risk**. Population, facilities and engineering objects, economic activities, public services and facilities, other infrastructure and livelihoods in the area potentially endangered.
- **vulnerability**. The degree of loss of a given element or group of elements in an area endangered by slide. It is usually expressed on a scale of 0 (no loss) to 1 (complete destruction). For property, the loss would be the value of the damage relative to the value of the property; for humans, the probability that a certain life (element at risk) will be lost if the person (s) is (are) endangered.
- **risk**. A measure of the likelihood and severity of adverse effects on health, property, or the environment. Risk is often regarded as the product of the probability of a given magnitude phenomenon multiplied by the consequences. However, a more generalized interpretation of risk involves a comparison of probability and consequences in an unproductive form. For qualitative risk assessment it is advisable to use the intensity of the sliding. In the context of these recommendations, risk is also assessed as:
    - **loss of lives**. An annual probability that people at risk will lose their lives taking into account the hazard of sliding, time-span probability and human vulnerability.
    - **loss of property**. Annual probability of a given level of loss or loss on an annual basis that takes into account the elements at risk, their temporal-spatial probability and vulnerability.
- **zoning**. Division of terrain into homogeneous areas, ie. domains and their ranking according to the degree of current or potential susceptibility, hazard or risk, or the applicability of certain hazard-related regulations.

The diagram in Figure 6 shows the general framework for managing landslide risk applied worldwide, and in some form has been applied here in North Macedonia for other terrains.

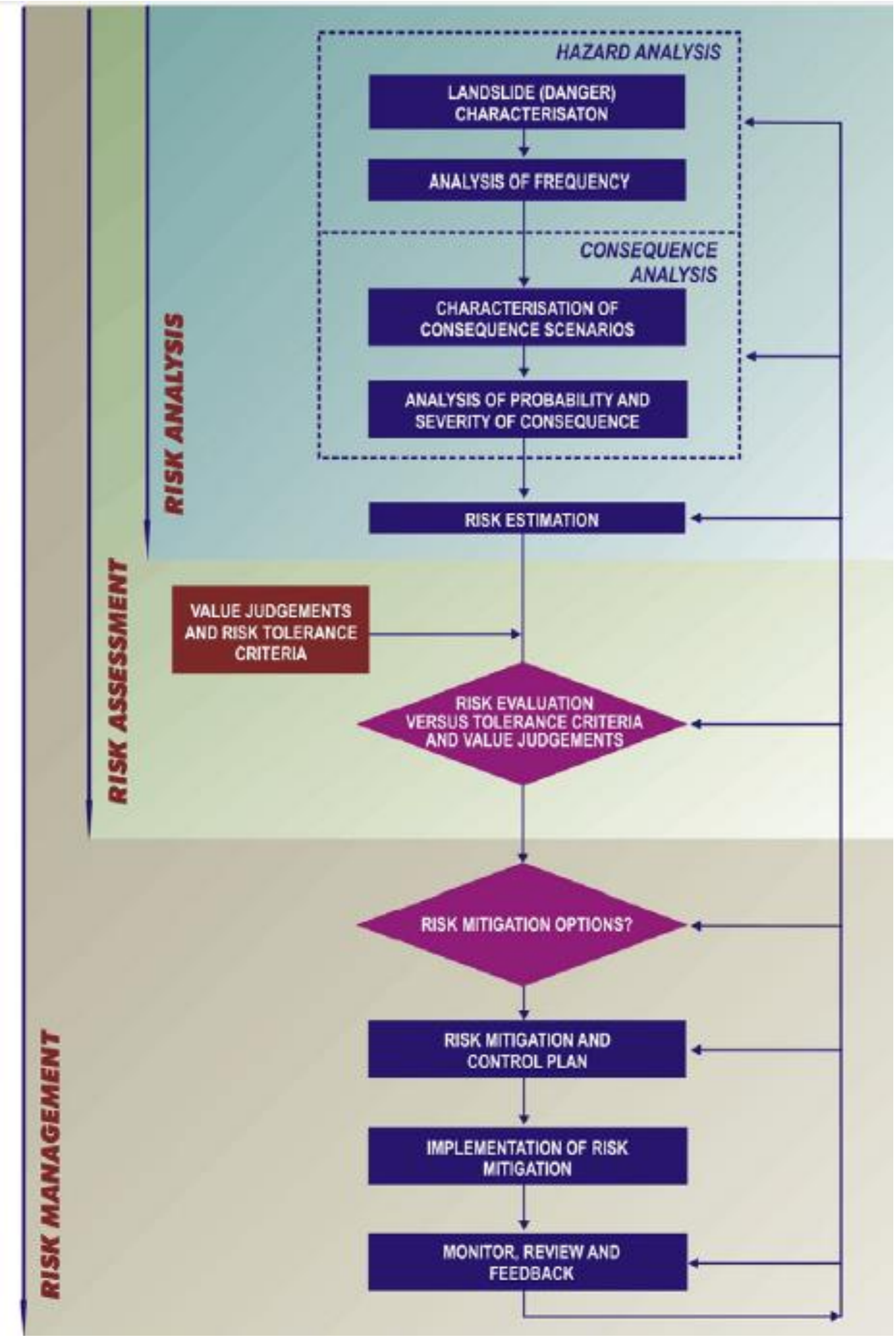

Figure 6. General landscape risk management scheme according to Fell R. et al. Engineering Geology, vol. 102, (2008) p. 85-98

According to the foregoing, due to the relatively small number of landslides in the past (although they were not rare in the region, according to the population), it is currently possible to develop only landslide inventory, while for other more advanced levels of terrain zoning (susceptibility, hazard and risk) conditions have yet to be created. However, even in the absence of more specific data, the landslide cadastre itself can be understood as a relative indicator of hazard and landslide risk. This does not mean that this issue should not be addressed in the future, but quite the contrary. The following tables provide recommendations from world literature on the level of detail when zoning the terrain in terms of landslides.

Table 2. Zoning types and levels, map scales associated with landslide mapping purposes (According to Fell R. et al. 2008)

Purpose	Zoning type				Zoning level			Possible scale of zoning maps
	Inventory	Susceptibility	Hazard	Risk	Preliminary	Medium	Advanced	
Regional zoning								
Informative	X	X			X			1:25,000 to 1:250,000
Advisory	X	X	(X)		X	(X)		
Statutory	Not recommended							
Local zoning								
Informative	X	X	X	(X)	X	(X)		
Advisory	(X)	X	X	X	X	X	X	1:5000 to 1:25,000
Statutory		(X)	X	(X)		X	X	
For the specific location								
Informative	Not recommended							1:5000 to 1:1000
Advisory	Usually not performed							
Statutory		(X)	X	X		X	X	
Project		(X)	(X)	X		(X)	X	
Note: X=applicable; (X)= could be applicable								

Table 3. Mapping scales for zoning landslides and their application (Fell R. et al. 2008)

Description of scale	Indicative range of scales	Examples of applying zoning	Usual surface
Small	<1:100,000	Landslide cadastre and landslide susceptibility for informing state institutions and the public	> 10,000 km^2
Medium	1:100,000 до 1:25,000	Landslide cadastre and zoning of landslide susceptibility for regional development purposes, i.e. large scale construction projects	1000–10,000 km^2
		Preliminary hazard mapping level (local level)	
Large	1:25,000 до 1:5000	Landslide cadastre, susceptibility zoning, and hazard (local level)	10–1000 km^2
		Medium to advanced level of hazard zoning for regional development	
		Preliminary to intermediate level of risk zoning (local level) and in advanced stages of planning large construction projects (structures, roads and railways)	
Detailed	>5000	Medium to advanced level of hazard and risk zoning (local level) and for specific locations and for design stages of large construction projects (structures, roads and railways)	several ha to 10 km^2

5. Mapping of existing landslides

5.1. Landslide cadastre for the Pelagonia planning region

All data collected during this research, for which the location of occurrence is known, is shown on the inventory map of unstable occurrences given in Annex No. C and Table 4. For some of the occurrences, the exact location was defined with the help of engineers who have done investigative or remedial work.

Appropriate GIS software ArcGIS 10.3 was used when entering data for unstable occurrences. All occurrences are applied as dot elements and labeled with the same tag no matter what type of displacement is involved.This is justified by the fact that for the most of the unstable phenomena that were taken from the Basic Geological Map the type of displacement is unknown. This situation can only be overcomed if systematically detailed field mapping and geotechnical research and investigations are carried out for the most problematic cases (field mapping, drilling, digging, geophysical and laboratory testing, etc.), which should be the subject of future studies.

The map is interactively linked to the internal database where all available event data is entered. In order to preserve this data in written form, an appropriate appendix No. V has been prepared providing the most important facts about all registered occurrences as well as information on where to find expert literature for most of them.

In the future the cadastral map and the database should constantly import all newly registered occurrences.

The creation of a database and maps of susceptibility, hazard and risk of unstable occurrences will improve the performance of institutions in charge for disaster management. Conditions will also be created for faster response, warning (population alert) and stabilization or prevention of landslides, monitoring of active occurrences and assessment of the possibilities of developing new landslides with greater or lesser impacts on the population and infrastructure.

5.2. Cadastral sheet for unstable occurrences

Based on the analysis performed, as one of the most comprehensive in content is considered the cadastral sheet for unstable occurrences, used for the Italian IFFI database (cadastre) according to Amanti et al. (1996 and version 2.33 by Amanti et al. 2001). The following is a brief summary of the cadastral sheet content that is proposed to be used for the GIS-bank of unstable occurrences in the Pelagonia planning region. This cadastral sheet has been proposed in previous studies concerning the establishment of a cadastre on the whole territory of North Macedonia. A copy of the cadastral sheet is given in Annex A.

The cadastral data sheet for unstable occurrences is divided into several sections:

- basic information
- last change
- geometry
- position of unstable occurrence
- geology
- land use

- exposition
- hydrogeology
- classification
- activity
- causes for occurrence of instability
- heralds of instability
- damage caused
- performed studies and research, repair measures taken
- graphical presentation of the occurrence (geological maps and profiles)
- geotechnical parameters of rock masses
- detailed information on population and infrastructure vulnerability
- calculation of damages and costs for performed investigative and repair activities.

The map shows a large number of landslides, and those that do not have a specific location are given a specification so that can be determined during a site visit.

Table 4. Overview of significant landslides in Pelagonia planning region

Serial number	Landslide (locality)	Registration date	Location of central point of landslide			Data source
			X	Y	Z	
1	Main supply channel of Strezhevo system (14 landslides)	1983	Position km 2+200, km 3+050, km 5+300, km 10+600, km 16+900, km 34+600, km 3+238-3+270, km 4+300-4+400, km 4+450, km 13+550-13+610, km 34+580-34+610, km 40+000-40+050, km 10+200, km 35+028-35+240			Technical report on the engineering-geological characteristics of rock masses along the route of the HMS Strezhevo main supply channel
2	Alimentation channel	Unknown	4542281	7521690	938	Elaborate on geotechnical research and testing on the landslide at km 8 + 650.00 from the alimentation channel on HMS "Strezhevo" near the village Dihovo, FCE 2015
3	Alimentation channel	Unknown	4538446	7526865	973	Elaborate on geotechnical research and testing on the landslide at km 21+300 from the alimentation channel on HMS "Strezhevo" near the village Oreovo, 2015
4	Main supply channel	Unknown	4555479	7519791	693	Elaborate on geotechnical research and testing on the indication of land sliding of the terrain at km 3+100.00 from the main supply channel on HMS "Strezhevo" near the locality Meckarica, 2015

5	Main supply channel	Unknown	4552196	7523992	687	Elaborate on geotechnical research and testing on the indication of instability on the ground at km 10 + 100.00 from the main supply channel on HMS "Strezhevo" at the locality Dragozhani, 2015
6	Main supply channel	Unknown	4550633	7525975	671	Elaborate on geotechnical research and testing on the landslide at km 13 + 960.00 from the main supply channel of HMS "Strezhevo" at the locality Dragarino, 2015
7	Main supply channel	Unknown	4549623	7527482	675	Elaborate on geotechnical research and testing at the landslide at km 16 + 300 from the main supply channel of HMS “Strezhevo” at the locality Jasina, 2015
8	Main supply channel	Unknown	4532563	7530162	649	Elaborate on geotechnical research and testing on the indication of landslide of the ground at km 41 + 590 from the main water supply channel of HMS "Strezhevo" at locality Canino, 2015
9	Main supply channel	Unknown				Executive Inspection Report and Investigative Drilling for landslide at 12 + 700 from supply channel of HMS "Strezhevo" near the village Dragozhani, 2015
10	Main supply channel, intake for REK Bitola, G0	2016	4550912	7525826		Technical documentation available at HMS "Strezhevo"
11	Landslide in the zone on the regional road M5 Bitola Resen in the zone	2010	4548338	7510787		Technical documentation available at PESR
12/1	Landslide in coal mine Suvodol	1992	4546995	7545726		Technical documentation available at REK Bitola
12/2	Landslide in coal mine Suvodol	1992	4544507	7545876		Technical documentation available at REK Bitola
13	Landslide on the road s. Magarevo to the children's resort (Pelister)	2011	4544431	7517191		Technical documentation available at PESR

14/1	Landslide on the bypass of Bitola	2013 2014/2015	4544789	7524917		Technical documentation available at PESR
14/2	Landslide on the bypass of Bitola		4545068	7524380		Technical documentation available at PESR
15	Landslide on the road Pretor - Markova leg (Resen-Border with Greece)	2017	4529745	7509930		Technical documentation available at PESR
16	Landslide on the road Krushevo-Demir Hisar	2010/2019	4578255	7520538		Technical documentation available at PESR
17/1	Landslide on the road Prilep Mariovo	2015	4569234	7546763		Technical documentation available at PESR
17/2	Landslide on the road Prilep Mariovo	2015	4569278	7547987		Technical documentation available at PESR

For some of these landslides that are of greater importance in the region, some detail is given in the next point within this Study, while some of the smaller occurrences are only indicated by their position in Annex C.

5.3. Description of some of the more significant landslides in the Pelagonia planning region

Landslide on the road M5 Resen-Bitola

During February 2010, on M-5 Resen to Bitola roadway a landslide occurred which caused significant difficulties in traffic. Namely, the landslide occupied most of the two lanes, with the tendency to catch the third lane, which was still used for traffic at the time of preparation of the information. The first occurrences of significant deformations were observed in the period of 20-21.02.2010, and the terrain movements were intensified on 21.02.2010. Then, the process of land sliding the terrain along with part of the carriageway accelerated, when a visible separation of part of the carriageway was observed. This is manifested by the appearance of an open crack and more than 20 cm of characteristic tension fracture of the carriageway itself. The length of the crack in the forehead is estimated at 60-70 meters, and there were some indications on the asphalt that the process could be extended to about 100 meters in length.

With the heavy rainfall that characterizes this time of year in this region, as well as the rapid melting of snow, the process of movement, and thus the instability of the rock masses along the slope, has gained in intensity the following days.

The sliding occurred at the contact of a basic rock mass with deluvial and embankment material from the road body. Due to the noted condition, it is estimated that the cause of the landslide was the excessive wetting of the substrate and its over-saturation, which was the ultimate reason for initiating the landslide at the contact between the embedded material (road embankment) and schist as the bedrock.

With the analysis of the situation and the appropriate technical solutions, the landslide was repaired, but the situation lasted for about 6 months, with all traffic being diverted locally to Makazi, Bitola. The situation is illustrated in the following photos (Fig. 7 to 10).

Figure 7. Frontal landslide fracture on 21.02.2010 with visible jump of about 0.6 meters and detachment of about 0.1 meters

Figure 8. Secondary landslide fracture on 21.02.2010

Figure 9. Condition of frontal fracture with jump over one meter on 22.02.2010

Figure 10. Landscape Reconstruction Phase general view (2011)

Landslides in the zone of water supply channel or alimentation channel of HS Strezhevo

In the framework of the Study, some of the most important phenomena on the channel network of HS "Strezhevo" are shown. These phenomena are documented with appropriate documentation, and their characteristics are defined by a set of geological and geotechnical investigations. Their existence has been known for a long time, and they are defined in more detail during 2012, by an expert team of geotechnical department at the Faculty of Civil Engineering, together with persons from PE "Strezhevo". The locations of these instabilities are shown on the overview map of the Strezhevo hydro system, shown in Figure 11.

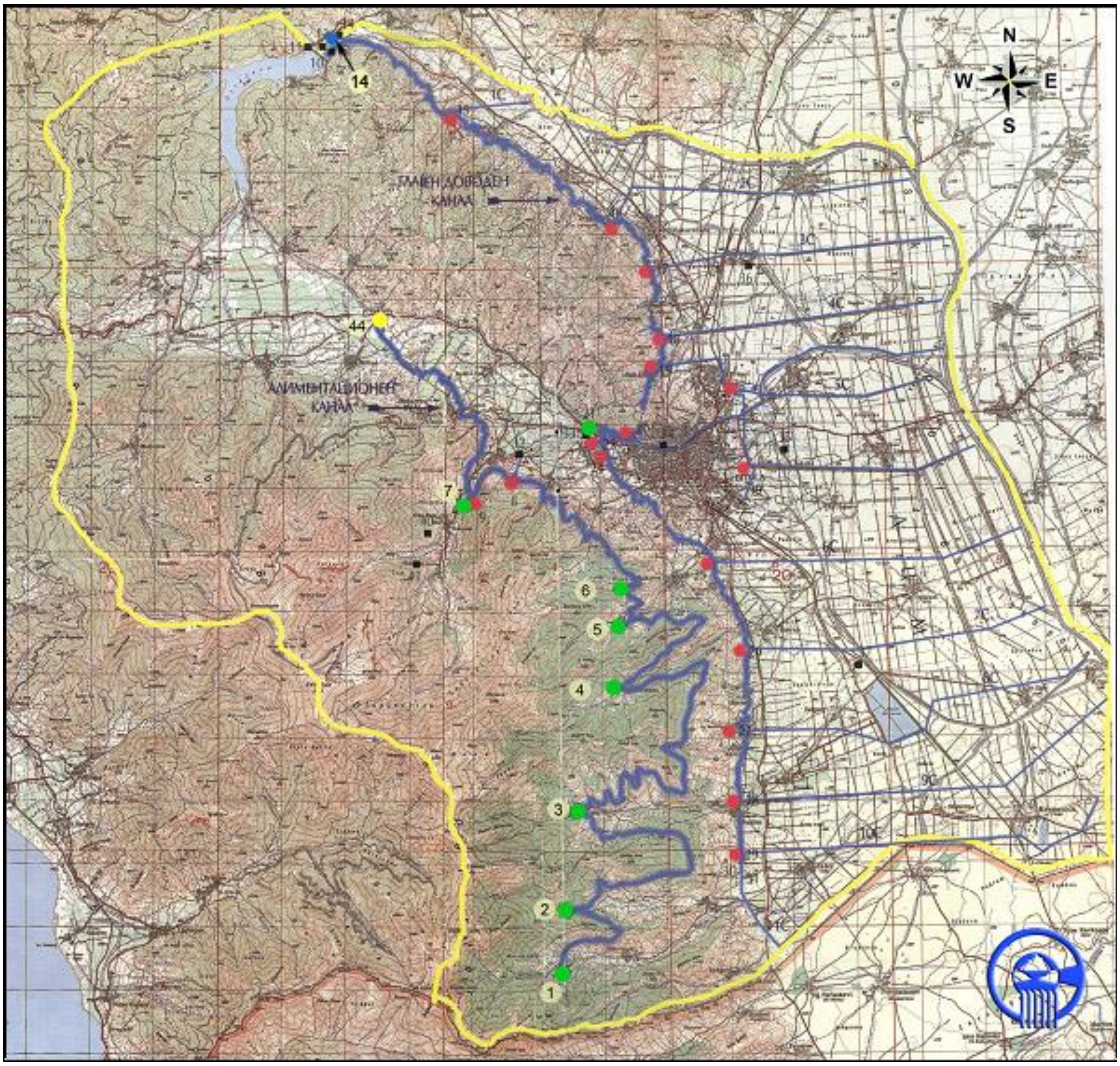

Figure 11. View map (situation) of the hydro system "Strezhevo" with position of registered instabilities on the terrain

The following is some of the most important landslide data.

Landslide at km 2 + 200

This landslide has been treated in the past, i.e. site investigations have been carried out. At this stage, 3 piezometers have been incorporated, but no measurements have been made so far, so there is insufficient knowledge of any improvements or stabilizations on the terrain. The landslide forehead (frontal cracks) were recorded on the access road next to the main supply channel (Figure 12), but were temporarily repaired (leveled and filled) for the purpose of enabling the road to function. During partial repair of the landslide, a drainage pipe was incorporated to collect the waters near the channel and take them to the collecting manhole (Figure 13).

Figure 12. Landslide location (source: Google Earth)

Figure 13. Current state of the landslide (source: photographed 29.03.2012)

From the inspections and consultations with the representatives of PE "Strezhevo" regarding the condition of the main water supply channel, it can be concluded that the landslide is currently in a stable condition, but not all measures for its final (permanent) stabilization have been undertaken.

Landslide at km 3+100

This landslide occurred during the construction of the main supply channel. At this stage, the forehead of the landslide over the supply channel was dispersed and directly endangered the stability of the channel (Figure 14). Inspection of the inside of the channel by experts from PE "Strezhevo", has revealed that there are longitudinal cracks on both sides of the channel and transverse breakage of the channel through tearing of the constructive reinforcement in the channel.

Figure 14. Landslide location (source: Google Earth)

Landslide at km 10+100

This landslide is located at km 10 + 096 just after exiting the aqueduct (Figure 15). Inspection of the inside of the channel revealed that there was a characteristic longitudinal crack (d = 20mm) on the right side of the channel at half the height of the crown in the form of shear. This crack is most likely to have occurred at one time, that is, the shear has occurred at a certain stage, after which the process has been settled for some time. This is concluded because in the next few observations on the interior of the channel, no change in crack size has been recorded.

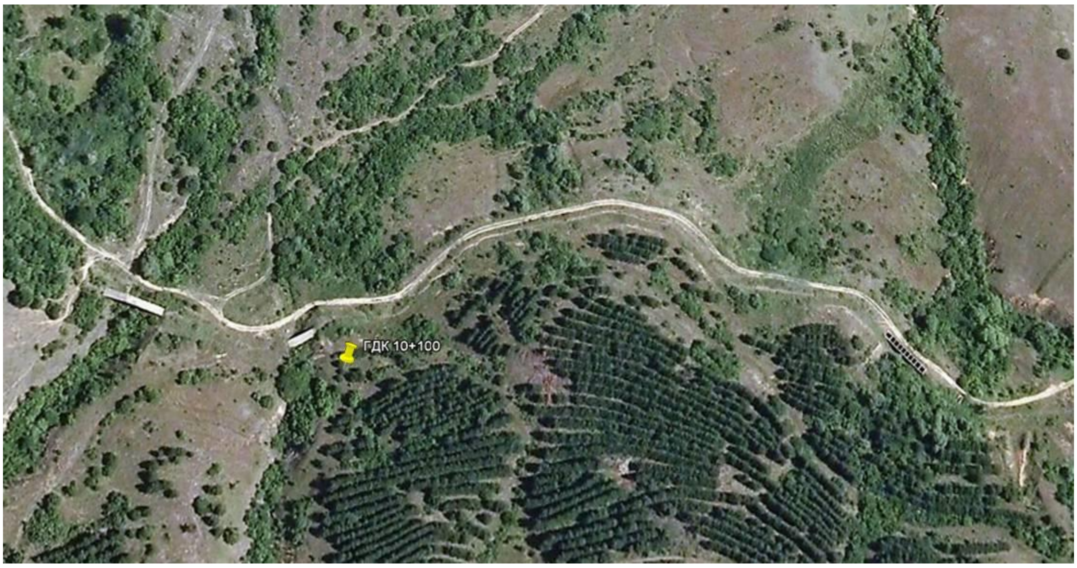

Figure 15. Landslide location (source: Google Earth)

Landslide at km 13+960

In this landslide during the exploitation phase of the channel, and also on the access road, a frontal crack appeared directly next to the road. For that purpose, the landslide forehead was loose to stabilize the access road, which is currently in stable condition (Figure 16). During the on-site inspection, the primary landslide cracks were noted which occurred in the first phase of the landslide, and the secondary cracks that occurred later in the past, thus defining the nature of the landslide and concluding that the landslide is currently in a "standby" phase (figure 17). During the inspection of the interior of the channel, it was noticed that there is a large segregated areas on the left side of the channel.

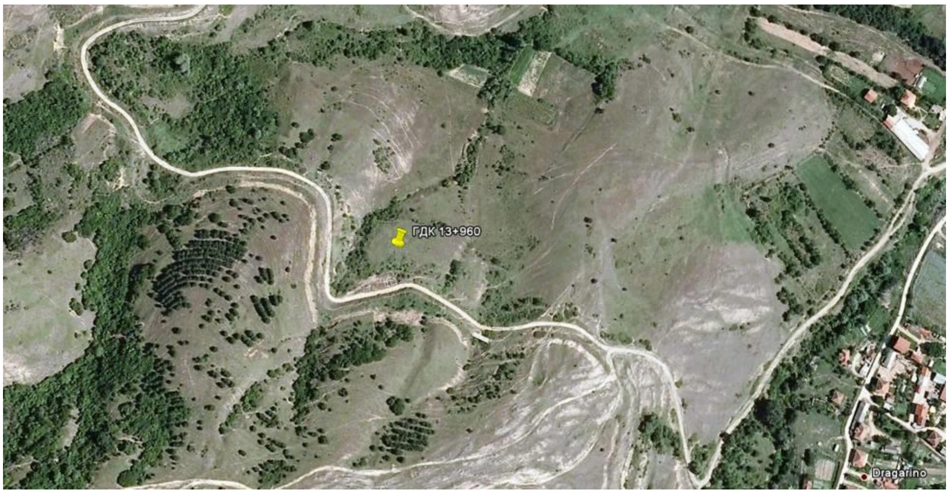

Figure 16. Landslide location (source: Google Earth)

Figure 17. Current state of the landslide (photo 29.03.2012)

Landslide at km 16+300

This landslide is located near the village of Kukurechani (Figure 18). The frontal crack of 35 cm is descending to the middle of the access road (Figures 19 and 20). In the immediate vicinity there is a spring whose waters are thought to be part of the water passing through the channel. This is supported by the data obtained during inspections inside the channel, which revealed that there is a large segregation of surfaces on both sides of the channel with longitudinal cracks in the crown and at the bottom of the channel. Figure 21 shows the curvature of the vegetation - a drunk forest which is another indicator of terrain movement.

Figure 18. Landslide location (source: Google Earth)

Figure 19. Current status of the landslide (photographed 29.03.2012)

Figure 20. Current state of the landslide (source: photographed 29.03.2012)

Figure 21. “Drunk forest” (source: photographed 29.03.2012)

Landslide at km 41+590

This landslide is located after the village of Canino (Figure 22). In the past it was partially dispersed from the top of the channel. Inspection of the inside of the channel revealed that there was a characteristic longitudinal crack (d = 10mm) on the right side of the upper third of the wall height formed during first-stage shear. Since then, no new shifts and cracks have been observed in the channel.

Figure 22. Landslide location (source: Google Earth)

Landslide at km 8+650 at the alimentation channel

This landslide occurred during the construction of the channel. So far some minor repair measures have been taken. Later in the past, near the channel, a new road Bitola - Nidze Pole was constructed. It has been found that there is a continuous sinking of material from the axis of the road to the slope (Figures 23, 24). In the immediate vicinity of the road is built a retaining wall of gabions (Figures 25, 26), which is currently visibly deformed in length, indicating that the landslide is not repaired by this measure, but additionally is loaded on the forehead. Going toward the toe of the landslide, there are existing structures in the immediate vicinity of which there are supporting structures of massive stone with obvious deformations in the form of slipping and rolling. In many places water springs have been found to form even larger watercourses.

The PE "Strezhevo" has made detailed recordings of the interior of the channel which shows damage to the walls of the channel. During 2011, restoration work was carried out to reinforce the channel plate slab, as well as replacing several roof plates with new serrated plates that cross the upper free ends of the walls.

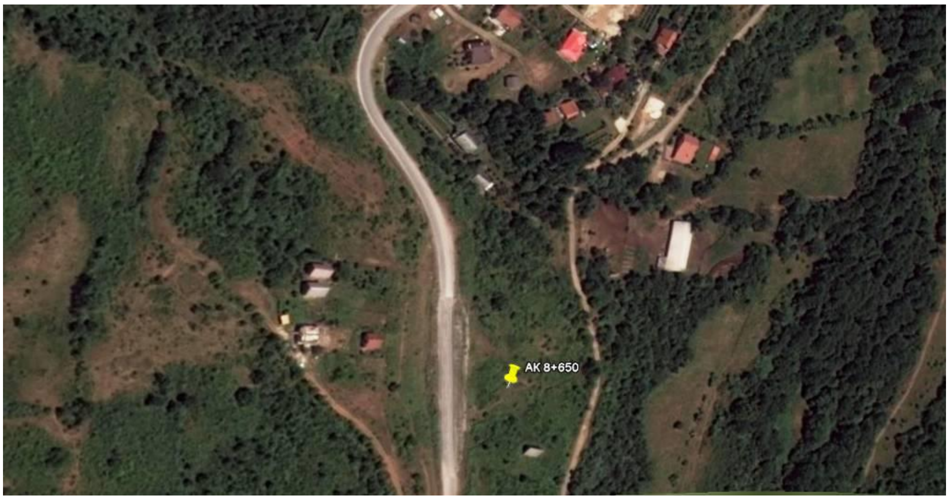

Figure 23. Landslide location (source: Google Earth)

Figure 24. Location of the alimentation channel in relation to the road Bitola - Nidze Pole (source: photographed 29.03.2012)

Figure 25. Cracks along the axis of the road Bitola - Nidze Pole (source: photographed 29.03.2012)

Figure 26. Location of support structure of gabions under the road Bitola - Nidze Pole (source: photographed 29.03.2012)

A Basic Rehabilitation design has been developed for this landslide, but the measures provided for the solution have not yet been applied.

Landslide at km 21+300 at the alimentation channel

In the past, this landslide was partially dispersed from the top of the channel, while acacia trees were planted on the lower side (Figure 27). During the inspection of the inside of the channel, it was found that there were damages to the channel. During 2011 renovation works were carried out to strengthen the channel floor slb and part of the walls. Cracks in the concrete for protection against water penetration have also been repaired.

Figure 27. Landslide location (source: Google Earth)

Landslides along regional road Prilep-Mariovo

These two landslides are developed within metamorphic rocks of gneiss or graphite schist. Figure 28 shows their position on the Basic Geological Map of the Republic of North Macedonia in a scale of 1: 100 000. Their occurrence was more clearly defined in 2015, when appropriate geotechnical investigations were undertaken.

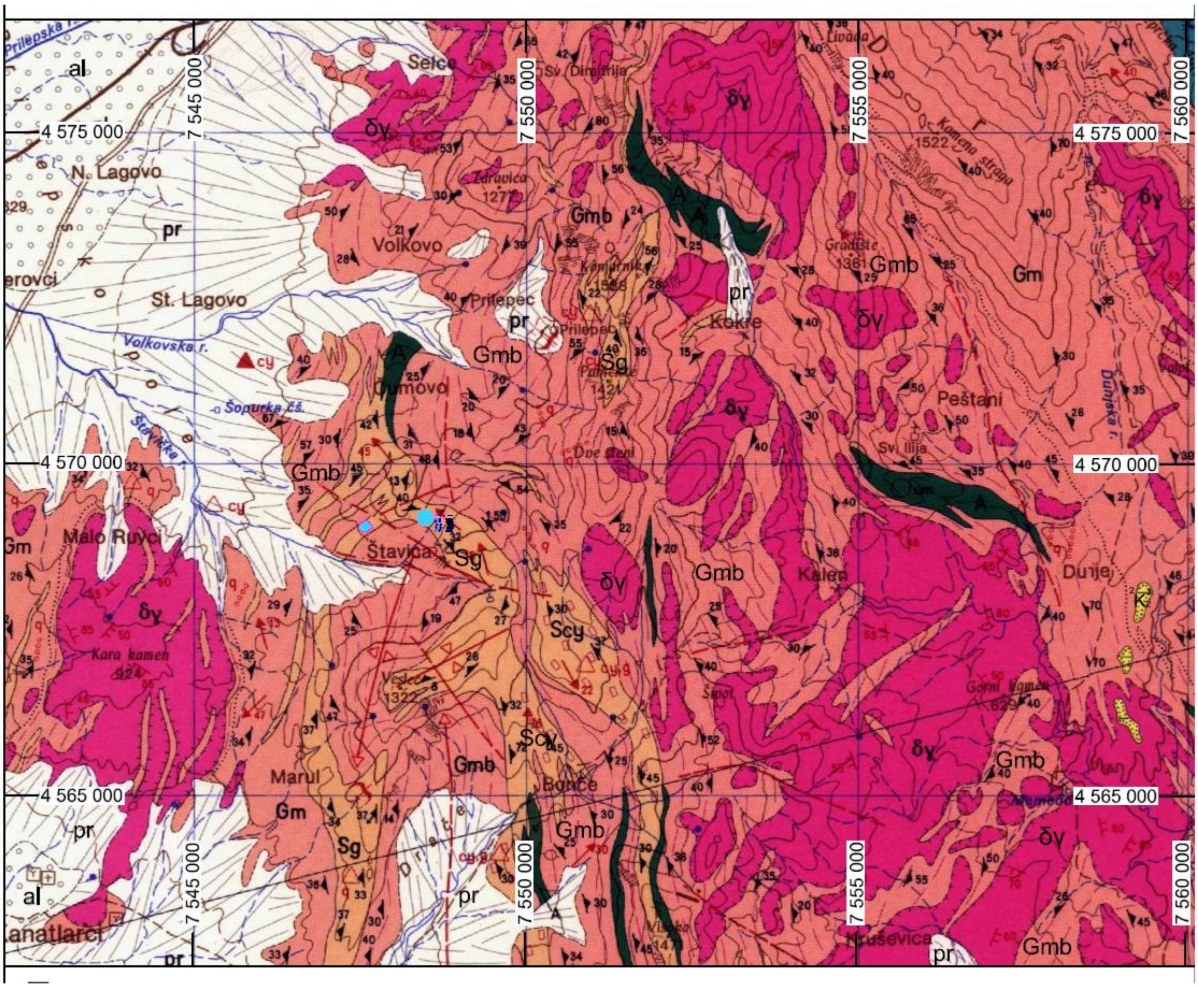

Figure 28. Landslide locations on regional road R1107 Prilep-Mariovo, km 34 + 500 and km 35 + 000 (BGM blue spots)

Figure 29. Landslide area just below the road at km 35 + 000

Figure 30. Landslide area adjacent to km 34 + 500

Basic reparation designs have been developed for these occurrences, but the measures provided as a solution have not yet been applied.

Landslides on the bypass of Bitola

At the Bitola bypass, during 2014/2015, on the A3 motorway, the Bitola bypass, there were landslides, which caused traffic congestion and redirection for about a year. The landslides are located at km 73 + 000.00 (higher occurrence) as well as 73 + 500 (lower occurrence).

From a geological point of view, masses that are affected by landslides and dislocations are fragments of deluvial quaternary sediments, together with part of decomposed metamorphic and magmatic rocks. According to the findings, a technical solution for remediation was developed in 2015 by the company Civil Engineering Institute of North Macedonia-Skopje. The position of landslides is shown in Figure 31.

Figure 31. Google Earth snapshot of the Bitola bypass landslides (the smaller area to the left is visible, while the larger landslide is clearly visible in the center)

It should be mentioned that these landslides are already repaired.

Landslide in SE part of coal O.P. "Suvodol" - Bitola

As part of the open pit mine for coal "Suvodol" - Bitola, there has been a rare example of a landslide that deserves a place in world literature. A very significant fact is that in the immediate vicinity, opposite the frontal crack, is the artificial Suvodol dam, about 1000 meters long and about 20 meters high, which accumulates the waters of the Suvodolka River. According to the dimensions of the phenomenon, this landslide can be treated as a "small tectonics" phenomenon. The first indications of a potentially instable mass, with a tendency for greater landslide, were observed back in 1992 when deformation affected the zone of the drainage tunnel at the Suvodol Dam. At this stage, tensile cracks up to 300 meters in length were clearly visible. During 1993, the potentially unstable zone was unloaded, which led to the apparent calming down of the process until mid-1994 when new cracks were observed. An important phase in the development of the landslide was in June 1995, when a large amount of rain (84 l / m^2) fell. A global slide occurred on October 27, 1995, when by usage of macroscopic and surveying methods large movements were registered, thrusting and folding in the toe of the mass. During the sliding, retrograde the masses were retracted throughout the terrain, so that eventually the landslide's forehead formed at a distance of about 260 - 300 meters from the body of the Suvodol Dam embankment, which can be seen on the engineering geological map of the terrain for the 1996 status and characteristic geological profile (Figures 32 and 33). It is important to note that due to the measures taken, the landslide didn’t cause human casualties nor captured machinery.

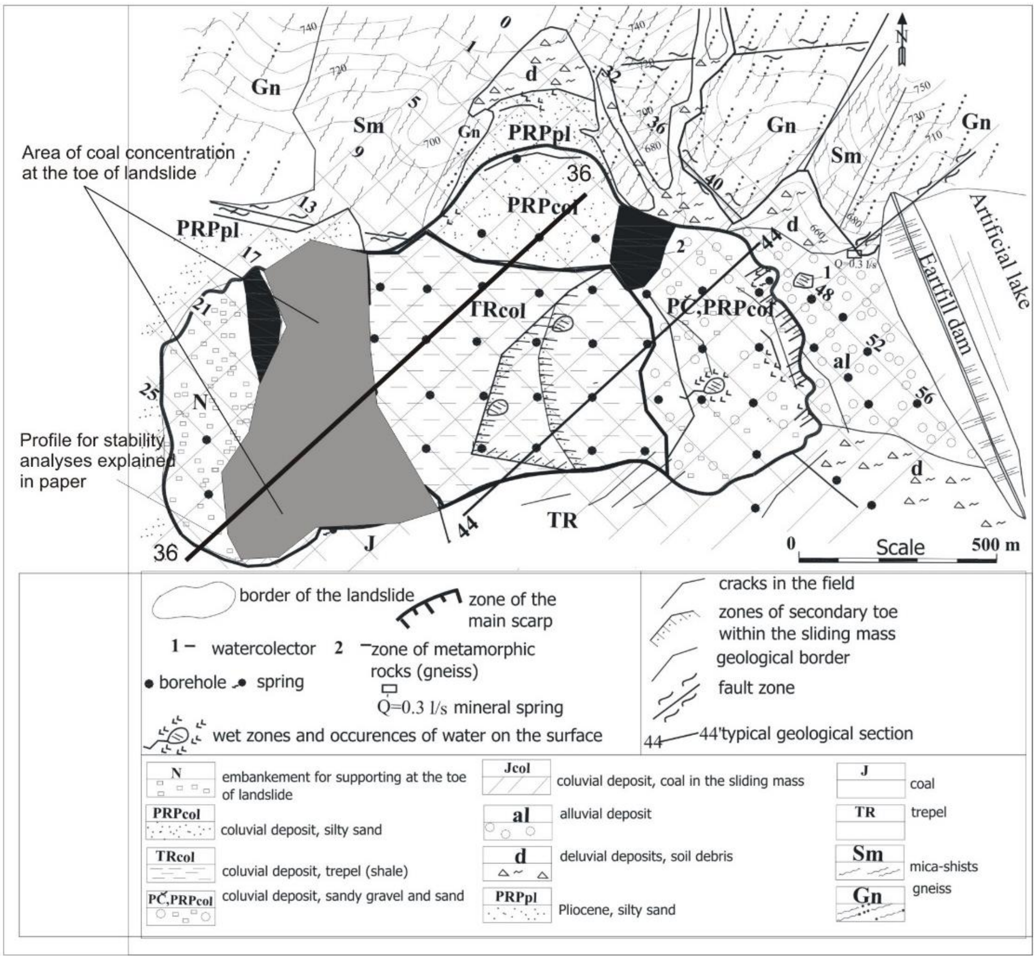

Figure 32. Engineering geology map of landslide in SE part of OPP. "Suvodol" - Bitola

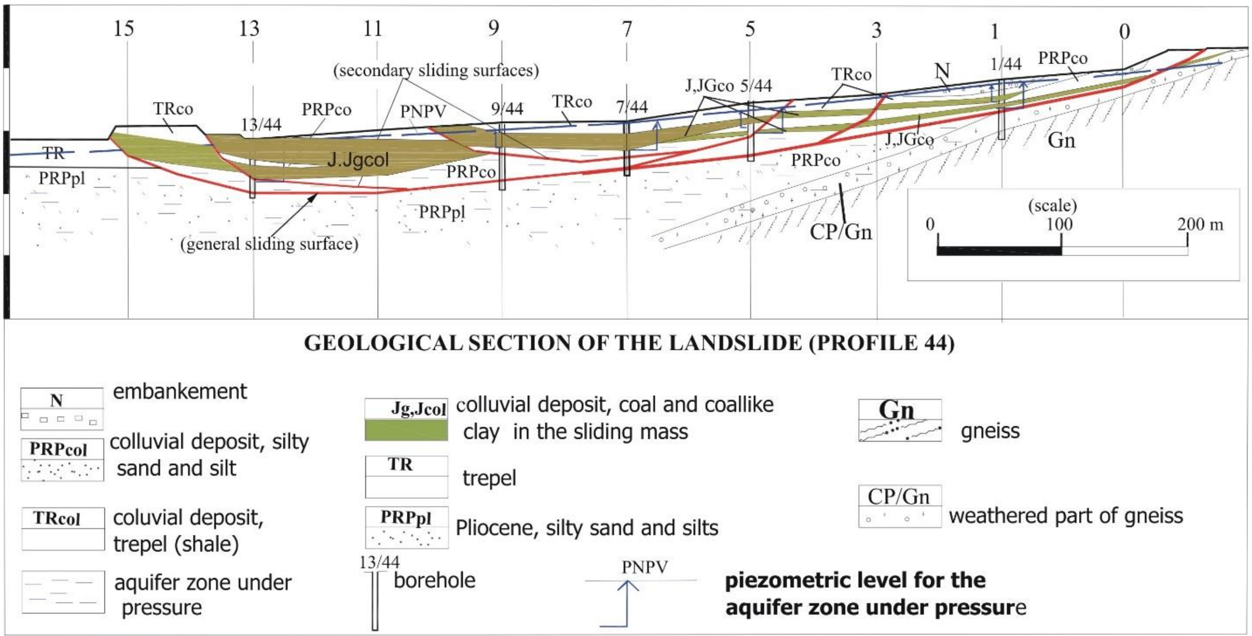

Figure 33. Characteristic geological profile of the landslide in the SE part of O. P. "Suvodol" – Bitola

Landslide on Regional Road R1308, section Pretor-Markova noga

This landslide occurred during 2017. From the geological point of view, the terrain masses affected by the landslide represent altered fractured parts of the granite masses, which have caused deformations of the road and redirection of traffic for almost a year (Figure 34).

Figure 34. Photo of landslide on Pretor-Markova Noga road

According to the findings, a technical solution for repair has been developed and is in the process of being tendered for construction.

From the examples shown, the impacts of landslides on infrastructure are clearly highlighted.

To illustrate the damages arising from landslides in the Pelagonia planning region, a certain scope of data is presented:

- Reconstruction of landslide in the zone of REK Bitola - G0, 150000 Euro for rehabilitation solution and performance of repair. Indirect damages due to eventual shutdown of REK Bitola due to water supply halt are estimated in millions of euros.
- Rehabilitation of six landslides in the zone of the supply channel of hydro system Strezhevo 255000 euros
- Landslide on the highway M5 Resen - Bitola - 600 000 Euro for repair of the landslide, additional indirect losses due to traffic interruptions, PESR
- Projected value for landslide remediation on the Pretor-Markova Noga motorway in the amount of approximately 2 700 000 Euros.

Of course, indirect costs due to traffic interruptions, increased gasoline consumption due to difficulties in traffic, disruption to emergency services efficiency, and environmental impacts are also significant.

6. Some data on the occurrence of floods and their consequences

Pelagonia valley is one of the most flood-prone regions in the country (Figure 35).

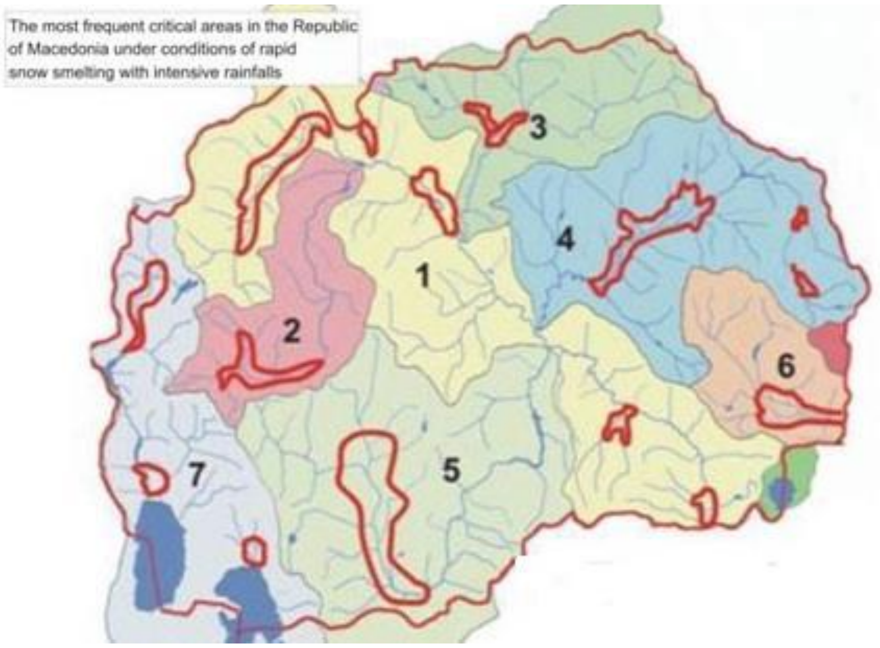

Figure 35. Critical flooding zones in the country (Source – Technical assistance preparation of climate resilience design guidelines for the Public Enterprise for State Roads in North Macedonia, IMC Worldwide, 2019)

Major floods in the past have occurred in the region in 1962, 1979, 1981 and 1986, and more recently in winter and spring 2015.

According to statistics, floods may occur at all times of the year, but are usually in late autumn or mid-winter, beginning in February-March, when snow melts due to the influence of the Mediterranean climate.

In the post-war period, catastrophic floods in Pelagonia were recorded in 1962, 1979, 1981 and 1986, but with less intensity. The following are excerpts from the book for Pelagonia Water Management, Bitola Field, Condition, Development and Perspective, Bitola 1998.

Flood November 1962
This flood, according to registered data, is caused by the occurrence of 80-year-old waters, which is far greater than the 20-year waters used in calculations. At Bucin water meter station 0 = 123.0 m^3 / sec is registered, which is considered as occurrence with 80 years possibility. This flood caused a flood of 25,000 ha in Prilep and Bitola parts of Pelagonia. The flooded zone in Bitola part of Pelagonia from the village Troykrsti was downstream was 3.5 - 4.0 km, and between the estuaries of the river Shemnica and the river Dragor the flooded area width was about 10.0 km. This flood beside the agricultural areas also flooded several rural settlements, the railway Bitola - Prilep, more roads of I category and other roads. Much of the regulated riverbeds and channels have been damaged.

Flood November 1979

Heavy rainfall in the Crna River watershed that fell from 16-21.11.1979 was 162.0 mm / m^2 with a daily maximum of 116 mm / m^2 (18.11.1979). These rains have caused 40 years of water, and at the station Buchin Mah O = 105.0 m^3 / sec. The riverbed of Crna River could not accept and evacuate these waters, so their outflow came. It has been recorded that 23,125 ha of agricultural land has been flooded at the outbreak of this flood. Since the end of regulation at the village of Buchin started the outflow of waters from both sides and from the regulated river bed of the river. The banks of the Crna River were destroyed in several places from Buchin to Troykrsti. In Prilep part of Pelagonija, the poured water flooded large areas of agricultural land from Buchin into the riverbed of Blato River. From the right shore the flooded waters flowed over the agricultural lands along the way, floating roads, railway and more. From the village Buchin in the direction of the village Novoselani, through the Ivanjevski channel, beside the village Vasharejca, floating the 2nd channel, the waters were moving parallel to the main river of the Crna River up to the inflow of the river Shemnica. Shemnica, Dragor River, 4th channel, 13th channel and 5th channel with the flooded waters of the Crna River flooded almost all agricultural areas on the right bank of the Black River, up to the inflow of the 5th channel. Downstream of the confluence of the 5th channel, a narrow strip of land along the Black River was flooded. On the left bank, the outflow of waters of the Black River started from the village of Troyrksti, towards the village of Topolchani. The groundwater line is oriented towards Dobrushevo beside the villages Aglarci, Dobromiri, Novaci, Ribarci, all the way to the village Gneotino. The whole fertile area of Bitola part of Pelagonia was practically flooded.

Flood March 1981

During this flood, 8.250 ha were flooded in Bitola part of Pelagonija. From the rains of 19 and 20.03.1981 the Crna River, 2, 5, 10, 13 channel, Velushka River, Lazhecka River and Eleshka River overflowed. The outflow of waters of the Crna River is registered on the left side of the village of Topolchani, and on the right at the inflow of the 2nd channel and at the inflow of the river Shemnica. The waters of the 9th channel were poured out and flooded areas from Aglarci to Gneotino villages.

Agricultural lands over 32.0 km were flooded from the left bank of the Crna River near the village of Topolchani and several channels. From the above mentioned 8,250 ha, flooded agricultural areas of ZIK "Pelagonia" were in the amount of 6,110 ha most of which planted with various crops and part of them prepared for harvesting. Several stables, roads and other infrastructure objects were destroyed during this flood. During this flood the profile in Buchin was measured O max = 68.40 m^3 / sec corresponding to the probability of occurrence of 10 year waters. The outflow of water is a consequence of the diminishing flow capacity of the riverbed.

Flood winter 1985/86

In addition to these larger floods, meanwhile, smaller floods have been reported which have not caused any significant damage to our economy. These minor floods have shaken the state of the drainage system and the need for its reconstruction and upgrading. During this winter, larger water were observed three times. 27.11.1985: due to the high water level of the Crna River, there is a slowdown in the regulated riverbed, where the water overflows through the channel embankments causing damages to them. No major damage was reported. Breakthroughs were registered at the Ivanjevski

Channel, 5th channel and Crna River at 12 + 500 km. On 20.02.1986 quite identical situation as at 27.11.85. and another warning about the state of the system. 04.03.1986: due to the high water level of the Crna River, the water in the 2nd channel of the river Shemnica, Dragor, 5th channel and 10th channel is slowing down. This occurrence prevents surface water from leaking into the surfaces in individual cartridges, thus about 3500 ha of agricultural land sown or prepared for sowing were under water. We note that in all three occurrences of which the last was the largest, the waters were smaller than the dominant 20 year waters. According to the collected data the damages from the flooded areas were as follows (Table 5):

Table 5. Flood overview in Pelagonia, source: Water Management of Pelagonia, Bitola field, condition, development and perspective, Bitola 1998

Year of flooding	Flooded area in acres	Amount in US dollars
1962	25.000	12.462.500
1979	23.125	11.235.210
1981	10.406	4.817.374
1986	8.250	1.419.099

The total damage to agricultural land in Pelagonia from the floods of 1962, 1979, 1981 and 1986 is estimated at $ 62.242.000.

Floods in 2015/2016

From recent history, it is important to note the floods in February 2015, when the rest of North Macedonia was also affected. Damages in the Pelagonia region were estimated at more than 7 million euros.
Based on the Initial Assessment of Damages and Needs (*Rapid Damage Needs Assessment* – RDNA, 2015), a total of six municipalities in the Pelagonia region (Crna River watershed) were affected by floods (Demir Hisar, Krivogashtani, Prilep, Bitola, Mogila and Novaci). The municipalities of Mogila and Novaci are one of the most affected by the flood wave. The most affected economic activity is agriculture (arable land), followed by damage to transport infrastructure and irrigation systems.
The floods in 2015 caused major damage to the country's transport infrastructure including roads and bridges at national, regional and local levels. The inspections carried out on 18.12.2015 and 26.01.2016 by a team of representatives of the local government, Faculty of Civil Engineering and UNDP, revealed major damage to part of the local road and channel. EKO-MAR company from Bitola has made certain hydrological and hydraulic analyzes for damages repair, primarily for the needs of the local Gneotino-Brod road, but the analysis is also partly intended for the entire Crna River basin, as well as for and some smaller tributaries.
In doing so, based on the analyzed segments of the watercourses (links between tributary joints) using data on accumulated flow and watercourses and determining the boundaries of the sub-flows, different models are formed, shown in Figure 36.

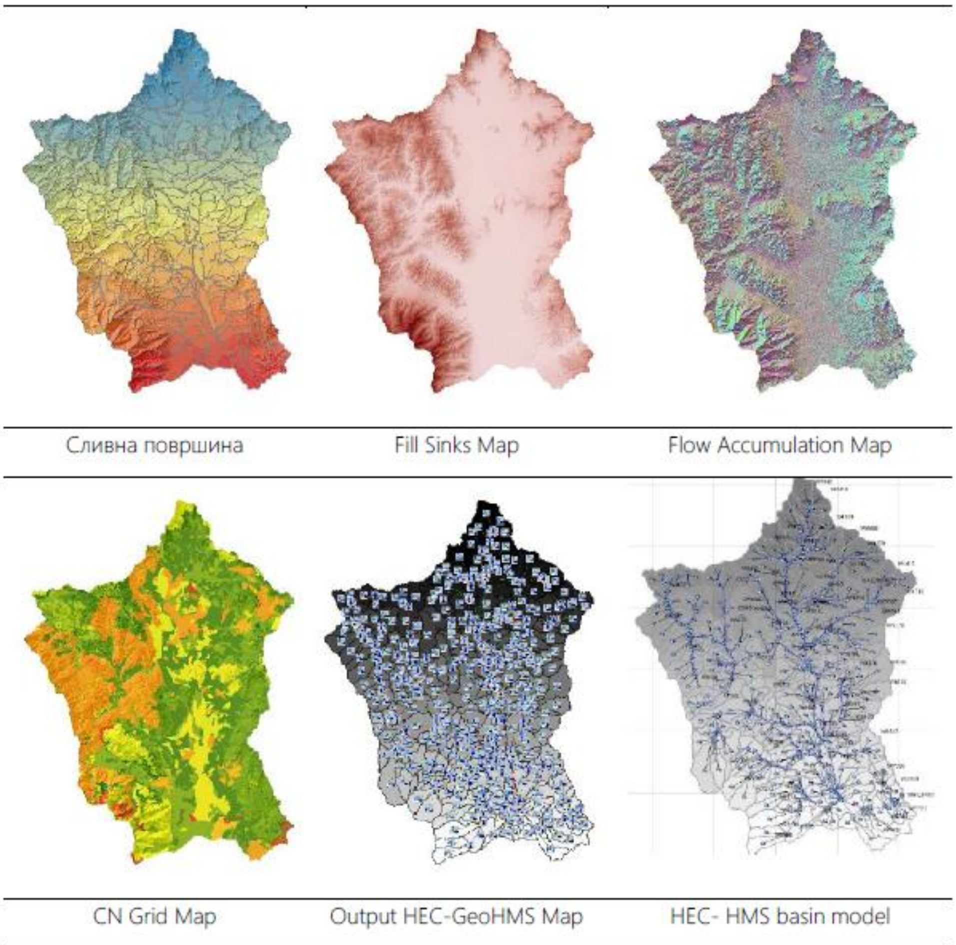

Figure 36. Models for Analysis of Hydrological-Hydraulic Data for the Crna River Watershed Source: Eco MAR, 2015

An example of defined flood zones arising from the general hydrological model of the Crna River, where sub-watershed that directly attack the Gneotino-Brod route are presented, and are further delineated into smaller sub-watersheds to obtain as realistic conditions as possible for the formation of flood waves (Figure 37). Other modeling results are shown in Figures 38 to 40.

Figure 37. View of the expected flood zone on the Brod-Gneotino route for a defined return period of precipitation

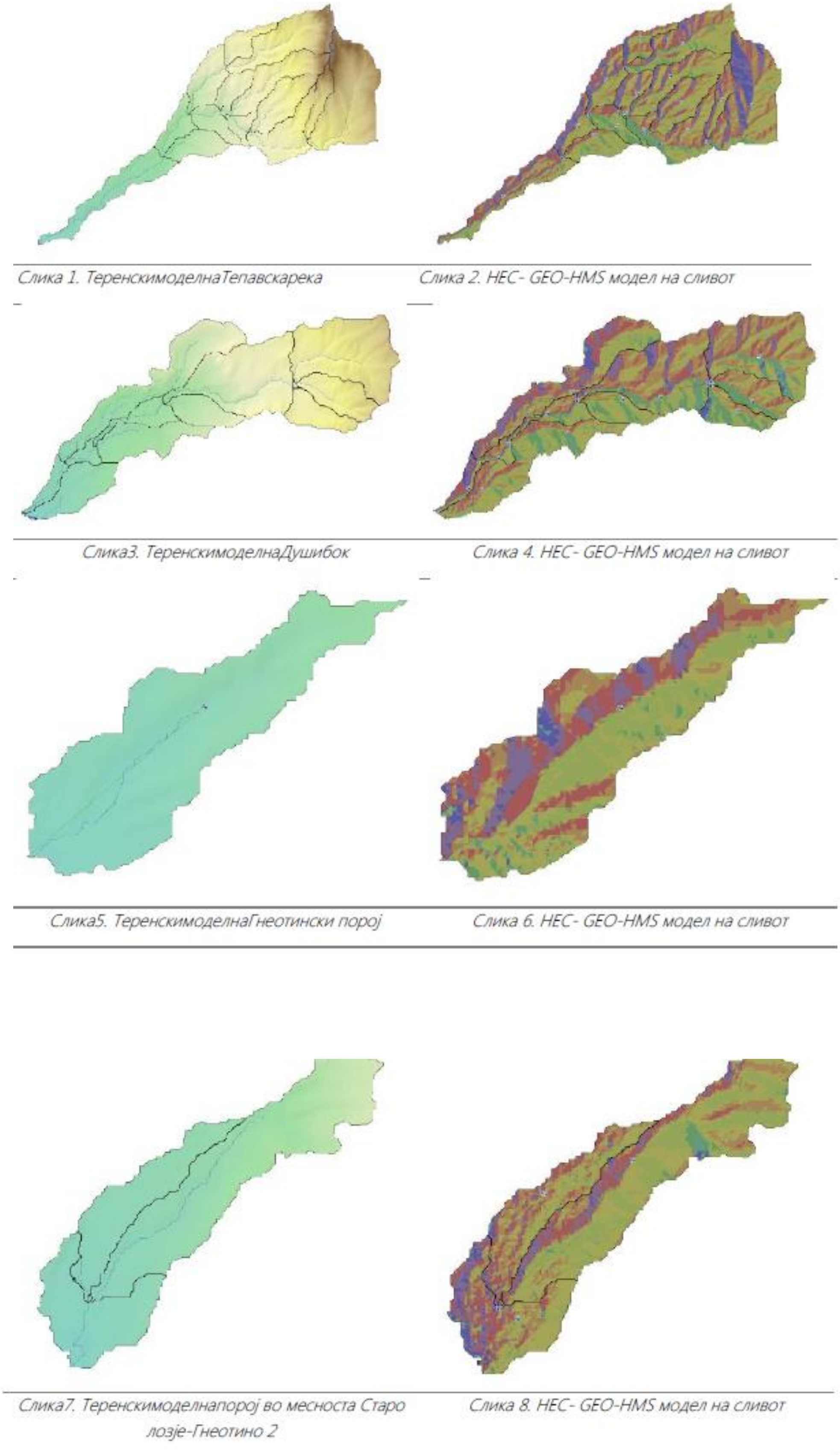

Figure 38. Results of hydrological modeling of several sub-watersheds in Pelagonia planning region

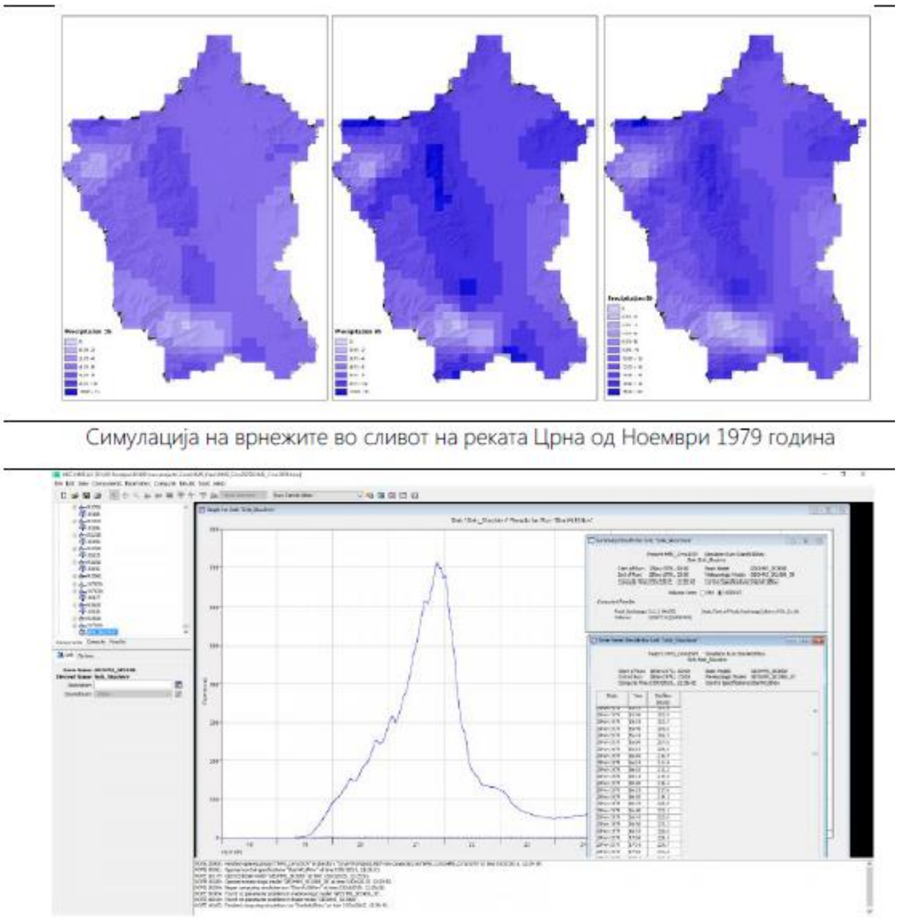

Figure 39. Simulation of precipitation in the Crna River watershed since November 1979

Some intensive precipitation data is shown in Table 6 for some watersheds.

Table 6. Summary results of hydrological models for significant regions and heavy rains, for different return periods

T god	P %	Gneotino	Tepavska	Gneotino 2	Dushibok
25	4	0.30	0.10	0.50	0.20
50	2	0.60	0.50	0.90	0.50
100	1	1.00	2.10	1.40	1.60

Figure 40. Flood zone simulation of high-water in Crna River with a 1% probability of occurrence in a 100-year return period

In general, it is considered that the part for flood impact analysis has great need of more detailed analysis and updating of the databases, since the facilities are dimensioned for lower probability levels of occurrence than required.
This should be the subject of some future study.

7. Preliminary identification of the most important factors causing landslides and floods

The very occurrence of landslides in our country is most often associated with periods of intense rainfall, low physical-mechanical parameters of rock masses, stronger earthquakes, reactivation of old "fossil" landslides, and are often artificially induced by current building interventions at the terrain, forest cutting and more.

Specifically in the Pelagonia planning region, landslides occur mostly due to heavy snow melting in the spring months or due to intense rainfall in a short period of time, which is possible at different times of the year. In some cases, the instability of the terrain is caused by a human factor. Particularly important to note is that in areas at the foot of mountains and parts of the terrain where there is fluvial-glacial sediments, the potential for landslides (and the number of registered landslides) is greater than the rest of the region.

As for the floods, it should be noted that with several stages of melioration, the potential for them is significantly reduced but not eliminated. Some recommendations are given above, and a more detailed review is provided in the second part of the project.

8. Features and benefits of establishing an early warning system for landslides and floods

Early warning systems are one of the methods of managing landslide and flood risk (and other natural hazards). These systems can be of a different nature and are defined as *monitoring devices designed to avoid, or at least minimize, the impact of hazards on humans, property, and the environment*. Lately, these systems have been increasingly used, primarily due to the decline in the cost of the electronic equipment necessary to operate them.

Establishing an early warning system requires careful approach and involvement of specialists from different fields. The main tasks of designing the system are: defining the needs and vulnerabilities of the at-risk population, identifying potential disruptions in the event of a warning, characterizing the geological and meteorological conditions leading to landslides (and floods).

Monitoring includes instrument installation, data transfer and processing, and is an essential part of the early warning system. In order to define appropriate thresholds for issuing a warning it is necessary to know the mechanism of the landslides (in case of possible flooding, prior linking of the measured precipitation data and flows with the performed flood altitude modeling). The basic components of the early warning system are shown in the following figure 41, while the basic mechanism of operation is shown in Figure 42.

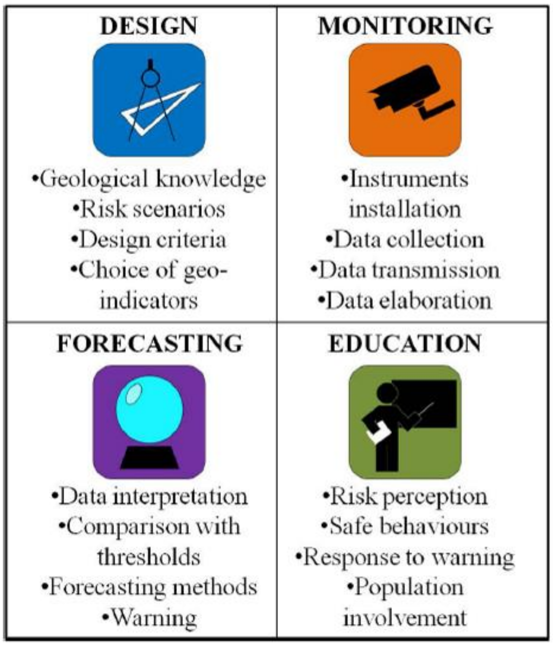

Figure 41. Separation of components of generic early warning system into 4 basic components, according to E. Intrieri, G. Gigli, N. Casagli, and F. Nadim. 2013.

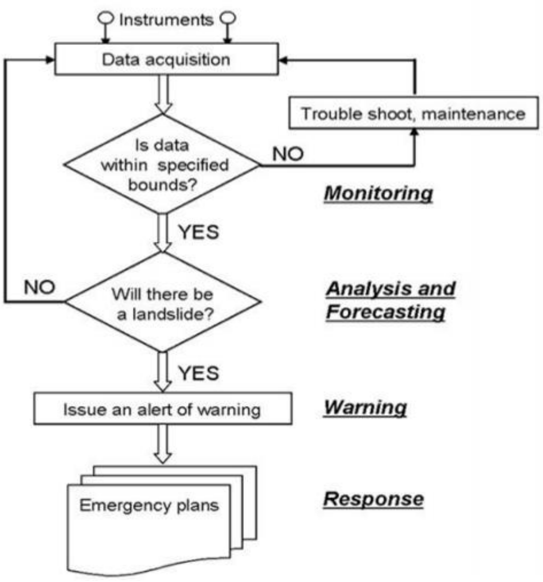

Figure 42. Mechanism of operation of an early warning system, according to Early Warning Systems for Landslides: Challenges and New Monitoring Technologies Farrokh Nadim International Centre for Geohazards / Norwegian Geotechnical Institute, Oslo, Norway Emanuele Intrieri University of Florence, Florence, Italy

Each individual early warning system is characterized by a specific internal structure. Due to the nature of this study we will not go into more detail about the possible instruments that would be incorporated in a warning system for the Pelagonia region, and furthermore because there is currently no adequate database available to link the activation of landslides at certain intensities of rainfall. This would be the the subject of study in some more advanced studies and analyzes.
As an illustrative example, Figure 43 illustrates the level of alert that is issued in the event of an increase in the intensity of the movement of benchmark points into a landslide body over the time. As soon as alarm level 5 is reached, an alarm is issued followed by evacuation. Figure 44 provides an example of the way that data flows into the generic system for landslide early warning.

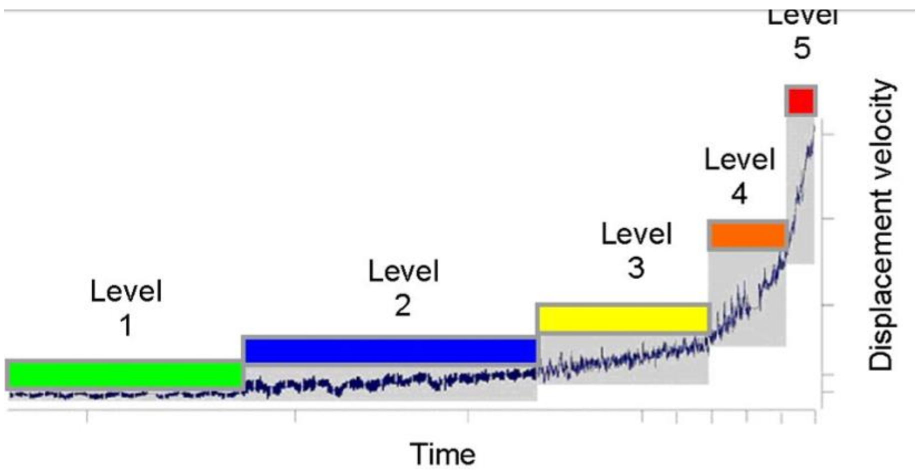

Figure 43. Illustration of alarm levels as a function of deformation velocity (vertical axis: degree of displacement in mm / day, horizontal axis - relative time before slope failure). It is mentioned that the curve is only for visual purpose, in order to help illustrate how the landslide is expected to behave before failure occurs (Blikra, 2008)

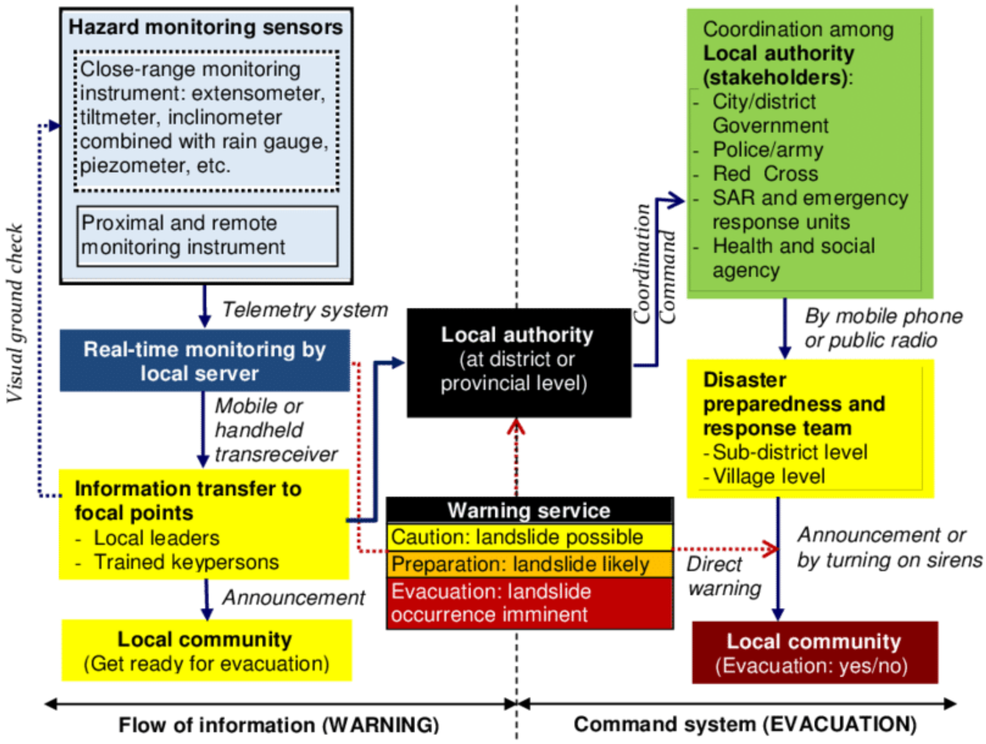

Figure 44. Data flow in early warning system according to Fathani, Teuku & Karnawati, Dwikorita & Wilopo, Wahyu. (2016).

9. Conclusions and recommendations

In addition to the general legislation, which clearly defines the roles of institutions in the event of natural disasters (extreme events), some of our recommendations are given below in order to further improve the risk management of landslides and floods. Recommendations are of particular importance and should be taken seriously in order to pay more attention to landslides as a natural hazard, and even more so because they are rarely mentioned in the legislation as hazardous with special characteristics. The following activities are recommended:

- Definition of developer and holder of GIS database for landslides and floods (Responsible Institution should be Geological Survey of North Macedonia or Directorate for Protection and Rescue).

- Realization of the proposed GIS database and putting it into operation with all the necessary elements (Geological Survey or Directorate for Protection and Rescue).

- Establishing contacts with European countries and engaging in projects dealing with landslide-type geohazards. The most experienced in Europe in this field are scientific and expert institutions from Italy, Switzerland, Spain.

- Selection of appropriate methods for assessment of landslide susceptibility / hazard and risk. Depending on the size of the area to be analyzed, a number of methodologies may be applied, and which methodology is most appropriate will be defined on the basis of the data collected in the GIS database. All data is processed and stored in a GIS system. This means that a gradual implementation of the activities is needed, in the order: forming a database (landslide cadastre, landslide susceptibility assessment, hazard assessment, risk assessment). Realization of these assessments takes a great deal of time and resources, and therefore requires the search for funds to carry out the proposed activities as soon as possible.

- Preparation of hazard and risk zone maps resulting from the above mentioned assessments. Such maps will serve as a thematic background that will need to be taken into account in all future spatial planning in order to reduce / eliminate the negative effects of landslides on the planned infrastructure.

- Inclusion of such maps in the legislation regarding building and environmental protection. The amendments to the legislation are an obligation of the Assembly of North Macedonia.

- Holding trainings and preparing recommendations for the citizens and the construction companies regarding the manner of performing the construction in the zones of high hazard of landslide. This responsibility falls under the authority of the Ministry of Interior Affairs and the Directorate for Protection and Rescue.

- Preparation of recommendations for citizens and construction companies on how to reduce the vulnerability of already constructed buildings in zones with high hazard of landslides. Obligation of local self-government and neighborhoods in cooperation with experts in the field.

- Definition of areas that restrict or prohibit the construction of buildings of different category due to the risk of landslides or floods. Ministry of Transport and Communications.

- All listed activities should be coordinated at national and municipal level.

The risks can only be reduced, but not completely eliminated. For these reasons, despite the above proposed measures, landslides and floods will still occur in the future (with the intention of anticipating and avoiding the danger, and by taking measures), so municipalities and institutions need to be organized and prepared to respond in case of their occurrence. This means maintaining a proper staff structure, organizational setup that will enable rapid response, operating funds, reserve funds and so on. Therefore, in order to raise the level of municipalities' ability to respond, some intervention in the legislation is needed, as well as education of staff and population in the region.

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EXECUTIVE SUMMARY

This study for landslides caused by floods in the Pelagonia planning region is based on available data on the natural factor, historical data on flood and landslide events, landslide and flood data analysis from our own databases, as well as on other sources.

The study's introduction highlights the problem of the impact of landslides and floods, and shows the documentation used in its preparation.

Chapter 2 presents the general features of the Pelagonia planning region, while Chapter 3 provides a thorough analysis of the natural factors, including the geological factors that are the most important prerequisite for landslides (and floods).

Chapter 4 is devoted to general definitions of landslides as natural hazards and their zoning, while Chapter 5 is specifically elaborated with a number of examples of significant landslides and their impacts on the region. This chapter is illustrated with a large number of photographs.

The next 6th chapter is devoted to floods in the region, with some indicative dates for events that have occurred so far. It is emphasized that the existing flood protection systems are of insufficient capacity and designed for a level of probability of occurrence which is insufficient for modern approaches to flood protection.

Chapter 7 is devoted to a preliminary identification of the most important factors causing landslides and floods, with particular reference to the Pelagonia planning region where it is concluded that landslides are most likely to occur due to intense snowmelt in late spring or due to intensive rainfalls in short time period, which are possible at different times of the year. In some cases, the instability of the terrain is caused by a human factor.As for the floods, it should be noted that with several stages of melioration the potential for them is significantly reduced but not eliminated. The recommendation for this part is to conduct specific studies to analyze precipitation impacts with a probability of occurrence once in a hundred years, after which more detailed analysis and development of appropriate projects may follow.

Chapter 8 lists some of the features and benefits of establishing a landslide and flood early warning system as one of the methods for managing landslides and floods (and other natural hazards). These systems can be of a different nature and are defined as monitoring devices designed to avoid, or at least minimize, the impact of hazards on humans, property and the environment. The main tasks of designing the system are: defining the needs and vulnerability of the population at risk, identifying potential disruptions in the event of a warning, characterizing the geological and meteorological conditions leading to landslides (and floods).

Finally, Chapter 9 outlines some of the responsibilities of the region's competent institutions for managing landslide or flood risk. It is emphasized that the legislation does provide some guidance on the role of institutions in the event of natural disasters (extreme events), however, some recommendations for action to improve the management of landslide and flood risk are presented here.

The final conclusion would be that in the future, comprehensive measures should be taken at national and regional level, and in the action plan a planning and strategic actions for a minimum of 10 years would be defined for the purposes of more detailed study analysis, design and ultimately undertaking of rehabilitation measures or building new facilities for the regulation of watercourses. Of course, every measure taken should be systematically monitored in order to respond to the challenges that are evident in the region.

Annexes

A. Cadastral (Inventory) sheet for unstable occurrences within the Pelagonia planning region

БАЗА НА ПОДАТОЦИ ЗА НЕСТАБИЛНИ ПОЈАВИ НА ТЕРИТОРИЈАТА НА Р.МАКЕДОНИЈА

Алфанумеричка ознака во банката на податоци: ______		ID број на појава	
Општи податоци			**Последна промена** ________
Датум на прв извештај		Координати X: ________ Y: ________	
		Регион	Општина
Изработувач на извештајот			
Топографска карта	Размер		Име на место

Геометрија / **Позиција**

		чело	местоположба	ножица
круната (m н. в.)	Азимут на насоката на движење α (°)	☐	Срт	☐
ножица (m н. в.)	Вкупна површина A (m^2)	☐	Висока	☐
Хоризонтална должина L_o (m)	Должина La (m)	☐	Средина	☐
Висинска разлика H (m)	Волумен на придвижен материјал V_f (m^3)	☐	Ниска	☐
Агол на косина β (°)	Длабина на рамнина на свлекување D_r (m)	☐	Речна доли.	☐

Геологија

Геолошка единица 1	Геолошка единица 2
Опис 1	Опис 2

Дисконтинуитет 1:
азимут / паден агол

Дисконтинуитет 2:
азимут / паден агол

1 2 Вид на слоевитост
☐ ☐ хоризонтална
☐ ☐ со пад во косината
☐ ☐ неправилна во однос на косината
☐ ☐ со пад надвор од косината
☐ ☐ со пад пострм од косината
☐ ☐ паралелно на косината
☐ ☐ со пад обратен од косината

1 2 Литологија
☐ ☐ варовник
☐ ☐ травертин
☐ ☐ лапорец
☐ ☐ флиш
☐ ☐ песочник
☐ ☐ шкрилец
☐ ☐ кис. изл маг. карпа
☐ ☐ баз изл. маг. карпа
☐ ☐ пирокласт. карпа
☐ ☐ кис. дл. маг. карпа
☐ ☐ баз. дл. маг. карпа
☐ ☐ метаморфна карпа
☐ ☐ евапорит
☐ ☐ седимент. Si карпа
☐ ☐ конгл. или бреча
☐ ☐ делувиум
☐ ☐ чакал
☐ ☐ песок
☐ ☐ прашина
☐ ☐ глина
☐ ☐ мешана почва
☐ ☐ вештачки насип
☐ ☐ друго

1 2 Структура на карпест масив
☐ ☐ масивна
☐ ☐ банковита
☐ ☐ слабо испукана
☐ ☐ средно испукана
☐ ☐ многу испукана
☐ ☐ шкрилеста
☐ ☐ сунгераста
☐ ☐ хаотична
☐ ☐ кавернозна

1 2 Растојание меѓу пукнатини
☐ ☐ многу големо (>2m)
☐ ☐ големо (60cm-2m)
☐ ☐ средно (20cm-60cm)
☐ ☐ мало (6cm-20cm)
☐ ☐ многу мало (<6cm)

1 2 Геотехнички својства
☐ ☐ карпа
☐ ☐ каменит материјал
☐ ☐ слаба карпа
☐ ☐ распадната карпа
☐ ☐ цврсто врзана почва
☐ ☐ слабо врзана почва
☐ ☐ врзана почва
☐ ☐ крупнозрнеста почва
☐ ☐ збиена почва
☐ ☐ растресита почва
☐ ☐ органска почва
☐ ☐ комплексна единица
☐ ☐ наизменични слоеви
☐ ☐ меланж

1 2 Распаднатост
☐ ☐ свежа карпа
☐ ☐ малку распадната
☐ ☐ средно распаднатa
☐ ☐ силно распадната
☐ ☐ деградирана
Забелешки

Користење на земјиштето

☐ урбани средини	☐ сезонски житарици	☐ пошумени терени	☐ без вегетација
☐ рудници	☐ постојани насади	☐ нискостебл. шуми	☐ грмушки
☐ обраб. земјиште	☐ крајбреж. вегетац.	☐ високи шуми	☐ пасишта

Експозиција

☐ N	☐ E	☐ S	☐ W
☐ NE	☐ SE	☐ SW	☐ NW

Хидрогеологија

Површинска вода
☐ нема
☐ стагнира
☐ дифузно истекување
☐ концентрирано истекување

Извори	Подзем. вода
☐ нема	☐ нема
☐ дифузни	☐ слоб. ниво.
☐ локални	☐ под притисок
Бр.	Длаб. (m)

Забелешки

Класификација

1°лив	1 2 Вид на нестаб. појава ☐ некласифиц.
☐	☐ ☐ одрон
	☐ ☐ обрушување
☐	☐ ☐ ротационо свлекување
	☐ ☐ транслаторно свлекување
☐	☐ ☐ хоризонтално ширење
☐	☐ ☐ бавно течење на почвата
☐	☐ ☐ брзо течење на почвата
☐	☐ ☐ понор
☐	комплексно свлечиште
☐	гравит. свлеч. со длабока рамнина на свлек.
☐	област со бројни одрони и превртувања
☐	област со бројни понори
☐	област со бројни плитки свлечишта

1 2 Интензитет на движење
☐ ☐ екстр. бавен (<5*10^{-10} m/s)
☐ ☐ многу бавен (<5*10^{-8} m/s)
☐ ☐ бавен (<5*10^{-6} m/s)
☐ ☐ среден (<5*10^{-4} m/s)
☐ ☐ брз (<5*10^{-2} m/s)
☐ ☐ многу брз (<5*10 m/s)
☐ ☐ екстремно брз (>5 m/s)

Забелешки

Страна **1** од **4**

Активност						
Состојба	☐ неодредено			Дистрибуција		Начин
☐ активно ☐ реактивир. ☐ смирено	☐ мирува	☐ стабилизирано ☐ вештачки стабил. ☐ напуштено	☐ реликтно	☐ во движење ☐ ретроградно ☐ со проширување ☐ со зголемување	☐ напредува ☐ намалува ☐ ограничено	☐ единечно ☐ комплексно ☐ композитно ☐ повеќекрат. ☐ сукцесивно
Датум на последно набљудување при кое е утврдено движење на теренот						
Извор на информацијата: ☐ весници, ☐ статии, ☐ очевидци, ☐ аудиовизуелно, ☐ архиви, ☐ картирање, ☐ далечинска детекција, ☐ историски документи, ☐ друго						

Причини за појава на нестабилната појава			
Терен-почва-карпи		Геоморфологија	
☐ слаб пластичен материјал ☐ чуствителен материјал ☐ распаднат материјал ☐ смолкнат материјал ☐ испукан или раседнат материјал ☐ неповолно ориентирана пукнат., слоевит, шкрил.	☐ неповолно ориентирани структурни дисконтинуитети ☐ контраст во водопропусноста ☐ контраст во кругоста	☐ тектонско издигање ☐ вулканско издигање ☐ глацијални процеси ☐ флувијална ерозија на ножицата ☐ ерозија од бранови на ножицата ☐ подзема ерозија, суфозија	☐ глацијална ерозија на ножицата ☐ ерозија на хоризонталните граници ☐ товарење на челото или растеретув. на ножицата ☐ отстранување на вегетацијата
Физички		Предизвикани од човекот (Инженерско-геолошки)	
☐ интензивен, краткотраен дожд ☐ продолжени периоди со врнежи ☐ брзо топење на длабок снег ☐ брзо спуштање на ниво на подземна вода ☐ брз пораст на ниво на подземна вода	☐ распаѓање поради мрзнење и одмрзнување ☐ термокластизам ☐ распаѓање поради бабрење и собирање ☐ физичко-хемиско распаѓање ☐ земјотрес ☐ рушење на природна брана	☐ ископ на косината или ножицата ☐ товарење на косината или челото ☐ испуштање на резервоари ☐ полнење на резевоари ☐ наводнување ☐ вид на посеви и методи на орање ☐ несоодветно одржување на дренажни системи	☐ течење на вода од канализација ☐ отстранување на вегетацијата ☐ рударство (површ.) ☐ рударство (подземн.) ☐ одлагање на многу растресит материјал ☐ вештачки вибрации ☐ усекување-засекување, ископ во теренот
Забелешка: X-предиспозиција, √ предизвикувачки фактор			

Предвесници на нестабилноста			
☐ прснатини, пукнатини ☐ локални вдлабнатини, микрорељефни форми ☐ локални одрони ☐ бабрење	☐ обратни градиенти ☐ слегнување на теренот ☐ пукнатини во објекти ☐ шкрипење на објекти	☐ хаотично навалени дрва или столбови ☐ појава на извори ☐ згаснување на извори ☐ згаснув. на водени токови	☐ пром. на издаш. на извори ☐ пром. на н.п.в. во бунари ☐ воден притисок во почвата ☐ подземни звуци

Штета				н.о. (не одредена)
☐ директна ☐ штета на резер. за вода ☐ блок. на воден тек ☐ блок. и лом на брана фор. со свлеч. ☐ лом на вештачка брана				
Луге ☐	☐ бр. на жртви	☐ бр. на повред.	☐ бр. на евакуир.	☐ бр. излож. на ризик
Објекти ☐	☐ бр. прив.	☐ бр. на јавни	☐ бр.прив. обј. под ризик	☐ бр. јавни обј. под ризик
Чинење (денари)	Поседи	Активности		Вкупно

Студии / истражувања		**Мерки за санација**		
Технички извештаи ☐ извештаи за локацијата ☐ геолошки извештаи	☐ идеен проект ☐ главен / изведбен проект	Земјани работи ☐ планирање ☐ растеретување ☐ подпора ☐ ограничување	Дренажа ☐ површ. канали ☐ дренажни ровови ☐ дренажни бунари ☐ суб-хор. дренажи ☐ дренажни тунели	☐ хидролошки зафати ☐ затревување ☐ засадување ☐ селект. сечење ☐ зас. врби, дрва ☐ загати, брани ☐ зашт. на реч. кор. ☐ зајакнување ☐ дрвени анкери ☐ спојки, анкери ☐ лепење ☐ инектирање ☐ микроколови ☐ топл. хем. електр. третман
Истражувања и мониторинг ☐ геолошки дупнатини ☐ геотех. лаб. испитувања ☐ хидрогеол. истражувања ☐ геоелектр. истражувања ☐ површ. сеизм. истраж. ☐ геоф. каротаж во дуп. ☐ пенетрометар ☐ пресиометар ☐ крилна сонда	☐ инклинометри ☐ пиезометри ☐ мерење на пукнатини ☐ екстензиометри ☐ клиномери ☐ мерење на слегнув. ☐ микросеиз. мрежа ☐ геодетски монитор. ☐ хидро-метеоролошки мониторинг ☐ други	Потпора ☐ габиони ☐ ѕидови ☐ прегради ☐ колови ☐ армир. земја	Заштита ☐ мрежа ☐ торкрет ☐ насипи ☐ ровови ☐ конструкции	
		Намал. на штета ☐ консол. на обј. ☐ демолирање	☐ евакуација ☐ алармни системи	
Потрошени средства за досега изведени истраж. (денари)	Планирани средства за изведени истраж. (денари)	Вкупни средства за изведени истраж. (денари)		

Библиографија						
Автори	Год.	Наслов	списание/книга/извештај	издавач/тело	бр.	страна

Страна **2** од **4**

Графичка презентација на нестабилна појава (геолошки и геотехнички карти и профили, истражни дупн.)

Опис на геотехничките параметри на карпестите маси кои се зафатени со процесот на свлекување

Страна **3** од **4**

Детални информации за повредливост на население и инфраструктура

Детален опис на претрпена штета и чинење на превезмени истражни и санациони мерки

Страна **4** од **4**

B. Photo documentation of some landslides in Pelagonia planning region

Landslides in the zone of the supply channel at Strezhevo hydro system

Landslides in the zone of the supply channel at Strezhevo hydro system

Landslides in the zone of the supply channel at Strezhevo hydro system

Landslide in open pit mine REK Bitola

Landslide on the M-5 Resen-Bitola regional road, February 2010

C. Geological map of Pelagonia planning region with locations of landslides