Civil Engineering – Survey, Design,
Construction, Consulting

# Provision of Geotechnical Investigation for New Road Tunnel and Overpass in Dariali Valley, Georgia

# TECHNICAL REPORT

**Tbilisi, Georgia**
**2017**

# Provision of Geotechnical Investigation for New Road Tunnel and Overpass in Dariali Valley, Georgia

# TECHNICAL REPORT

L. Mikaberidze
General Director
GeoEngineering Ltd

L. Gorgidze
Director, Department of Engineering Investigations
GeoEngineering Ltd

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# C O N T E N T

**TEXTUAL PART**

## GRAPHICAL PART

| No. | DRAWING NAME | DRAWING NUMBER | NUMBER OF SHEETS |
|---|---|---|---|
| 1 | Engineering-geologilca Map, scale 1:2000 | GC-1701-1 | 1 |
| 2 | Engineering-geological Long Section of Tunnel (Option I), Scale 1:1000 | GC-1701-2 | 1 |
| 3 | Engineering-geological Long Section of Tunnel (Option II), Scale 1:1000 | GC-1701-3 | 1 |
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## ANNEXES

| No. | ANNEX NAME | NUMBER OF PAGES |
|---|---|---|
| 1 | Resistivity sounding (Electrical Resistivity Test) results | 11 |
| 2 | Photographical documentation | 2 |

# 1. INTRODUCTION

This Technical Report provides results of geotechnical survey of the designed new motor road tunnel in Dariali valley, Georgia.

Administratively the construction site of the tunnel belongs to town Stepantsminda Municipality and is located in 8 km distance northward, close to the Russia-Georgian border. The survey has benn conducted under the Contract # GC-1701 signed January 8, 2017 between Landsvirkjun Power ehf Ltd (Customer) and GeoEngineering Ltd (Contractor).

The content of the Geotechnical report is based on field works and existing library and literary materials, as was defined in the Contract. The field work included engineering-geological reconnaissance of the construction site and survey of the soils along the designed route by means of geophysical survey, in particular by Electrical Resistivity Testing. The main data for clarification purposes, like geological environment of the tunnel and geotechnical conditions, were taken from engineering-geological investigations and various as-built documentaion of the tunnels of the already constructed Dariali HPP, which were being prepared by GeoEngineering Ltd in 2011-2015 period. The area which was surveyed for the Dariali HPP includes the new motor road tunnel site entirely, whereas one of its tunnels (namely underground access tunnel to generator hall) is located in parallel to the designed motor road route, in the same line. Thus, the data which are based on the field work and existing various library materials, creates a solid base for proper interpretation of geotechnical conditions of the motor road tunnel.

According to the design, the motor road tunnal shall be located at the place where the riv. Devdoraki (flowing from the left slope) joins the riv. Tergi. The source of riv. Devdoraki is situated at the steep slope of the ice cap mountain (Kazbegi) and periodically, mudflows of high destructive power are formed in it. Due to the narrowness of the riv. Tergi valley bottom, mudflows have been always created danger for the road and other communications located at the rigth bank of the riv. Tergi, that make it neccesary to built a tunnel here.

Field and desktop works carried out for assessment of geotechnical conditions of the motor road tunnel construction site, accprding to the Contract terms, are given in Tables 1.1 below.

***Table 1.1 List of performed works***

| Item No. | Item Description | Actual Quantity |
|---|---|---|
| 1 | Mobilization/demobilization to project area of all equipment and personnel | 1 |
| 2 | Study and analysis of the previously conducted surveys data and Dariali Tunnels documentation | 1 |
| 3 | Engineering-geological reconnaissance of Tunnel and South Portal of Tunnel (approx 1.4 km) | 1 |
| 4 | Resistivity sounding (Electrical Resistivity Test, approx 30 m depth), from the south portal of tunnel up to 350-390 m length | 9 |
| 5 | Preparation of Technical Report based on the results of works; printing of 1 copy in Georgian and 1 copy in English. The report contains geological long sections of the south portal site of the tunnel. | 1 |

# 2. DESCRIPTION OF THE ENVIRONMENT

## 2.1 CLIMATE

Climate data for the location of the motor road site and adjacent area has been obtained from the Georgian Climatological Norm - PN 01.05-08, according to the data from Stepantsminda meteorological station. Based on the main properties given in Table 2 of the above mentioned norm, the project territory is attributed to Ic subdistrict. Climate properties are given in the tables below.

***Table 2.1.1 Main climate properties of the climate subdistrict***

| Climate district | Climate subdistrict | Average temperature in January, °C | Average wind speed of 3 winter months, m/sec | Average temperature in July, °C | Relative humidity in July, % |
|---|---|---|---|---|---|
| I | Ic | From -4 to -14 | - | From +12 to +21 | - |

***Table-2.1.2 Air temperature and humidity***

| # | Climate property | By month | | | | | | | | | | | | Yearly |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | I | II | III | IV | V | VI | VII | VIII | IX | X | XI | XII | |
| 1 | Average Monthly and Yearly Air Temperature, $^0$C | -5.2 | -4.7 | -1.5 | 4.0 | 9.0 | 11.8 | 14.4 | 14.4 | 10.6 | 6.6 | 1.5 | -2.6 | 4.9 |
| 2 | Mean Minimum Air Temperature, $^0$C | -34 | | | | | | | | | | | | |
| 3 | Absolute Minimum Air Temperature, $^0$C | 32 | | | | | | | | | | | | |
| 4 | Mean Maximum of the hottest month, $^0$C | - | - | - | - | - | - | 20.3 | - | - | - | - | - | - |
| 5 | Range of ambient temperature, $^0$C | 9.5 | 9.6 | 10.5 | 10.6 | 10.2 | 10.4 | 9.5 | 11.2 | 10.2 | 10.3 | 9.5 | 9.8 | - |
| 6 | Relative air humidity, % | 62 | 63 | 66 | 69 | 70 | 71 | 74 | 72 | 72 | 67 | 64 | 61 | 68 |

***Table-2.1.3 Amount of precipitation and snow cover***

| Amount of precipitation in a year, mm | Amount of precipitation in 24 hours, mm | Weight of snow cover, KPa | Number of days with snow cover | Water content in snow cover, mm |
|---|---|---|---|---|
| 786 | 111 | 0.84 | 104 | 180 |

***Table-2.1.4 Standard values of wind pressure***

| $W_0$ Once in 5 years, KPa | $W_0$ Once in 15 years, KPa |
|---|---|
| 0.23 | 0.30 |

***Table-2.1.5 Greatest wind velocity with probability once in 1, 5, 10, 20 years, m/s***

| in 1 year | in 5 years | in 10 years | in 15 years | in 20 years |
|---|---|---|---|---|
| 18 | 20 | 21 | 22 | 22 |

***Table.2.1.6 Frequency of wind directions***

| Wind property | | Direction | | | | | | | | Calm |
|---|---|---|---|---|---|---|---|---|---|---|
| | | N | NE | E | SE | S | SW | W | NW | |
| Frequency of wind directions (%) | January | 11 | 1 | 1 | 4 | 70 | 13 | 0 | 0 | - |
| | July | 46 | 4 | 2 | 3 | 36 | 5 | 1 | 3 | - |
| Wind direction and calm frequency (%) in a year | | 25 | 2 | 1 | 4 | 57 | 9 | 1 | 1 | 33 |

***Table 2.1.7 Standard seasonal freezing depth of soils, cm.***

| Clay and loam soil | Fine sand and silty sand, sandy clay | Fine and coarse sand, gravelly sand | Macro-fragmental soil |
|---|---|---|---|
| 83 | 100 | 108 | 124 |

## 2.2 GEOMORPHOLOGY AND TERRAIN

The upper part of the r. Tergi, from village Kobi to town Stepantsminda, has NE orientation, while below Stepantsminda it has northward orientation. Its valley bottom on Kobi-Stepantsminda segment lowers at about 200 meters. Its absolute elevation near Stepantsminda is 1730 m above sea level, while below Stepantsminda, in Dariali, at the intended location of the motor road tunnel, the Tergi riverbed falls sharply and this elevation within the area of village Gveleti is about 1350 m, and at the northern border of Georgia it falls to 1200 m. At a certain period of its formation, the valley morphology was affected by a massive landslide from the Kuro mountain ridge and mud-flow cones located on it, where currently town Stepantsminda is located. This very boundary is considered to be the start of the Dariali valley bottom, from which inclination of riverbed of the r. Tergi and therefore the rate of flow, increases sharply.

The narrowest rocky part of the Dariali gorge, within which the motor road tunnel will be located, as a result of erosional action of the r. Tergi and its tributaries cuts down into the Paleozoic granites and Jurassic shale rocks. On the right flank of the gorge, within the depth of which it is intended to locate the tunnel, as a result of erosional-denidational processes landforms of various character have formed. The variety of the landforms on the slope is conditioned by its lithology and tectonical structure, existence of hard, cleaved rocks, Quaternary ice-born sediments and fluviatiles, as well as colluvial rock riprap and other Proluvial (mudflow) formations . Along the right bank of the river, rock scarps alternate with the erosional gulleys, the bottoms of which is covered everywhere with colluvial cobble and boulder screes. Thus, the forestless, sometimes bushy Tergi gorge is characterized by complicated and severe landform conditions created by erosion and other active denudation processes.

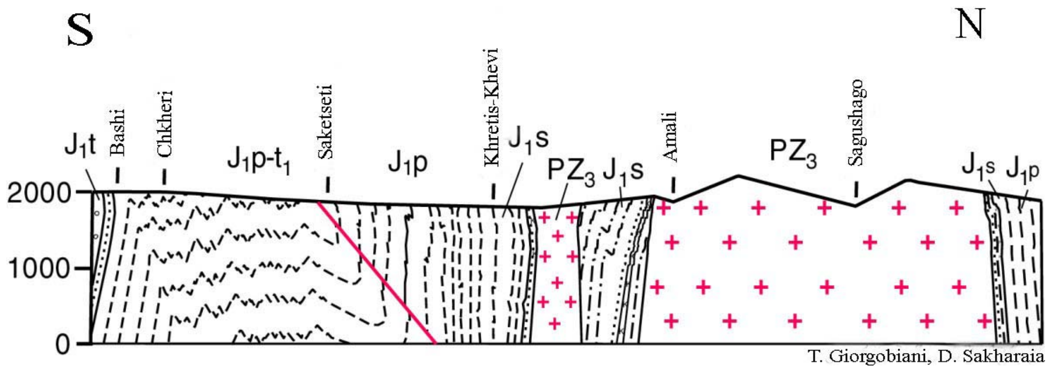
The part of the right slope of the gorge, where it is intended to locate the motor road tunnel, represents a steep rocky flank, with harsh erosioal trenches and collapsed boulders and cobbles concentration on some sites of the slope bottom.

The Dariali valley bottom, below Borough Stepantsminda area, and especially at the location of the motor road site, is narrow. Here, it is almost completely occupied by the river bed and the roadway.

## 2.3 GEOLOGICAL STRUCTURE

Tectonically the territory, where the motor road tunnel and surrounding areas shall be located, is included within the area of the Caucasus Mountains. It is mainly structured with Lower Jurassic, almost homogenous clay slate and slate members, with rare thin bands of siltstones and sandstones. Two stratigraphical units are differentiated in them: Plinsbachian-Lower Toarcian Tsiklauri and Sinemurian Kistinka suits. In the latter northern part of the mentioned segment, located are Upper Paleosoic Gveleti and Dariali granitoid solid masses ($\gamma Pz_3$). Apart from this, on the concerned area, various thickness diabase dikes are widely spread, which cross granitoids and granitoid-containing folded structures developed in the Lower Jurassic clay slates. The upper part (south) of the motor road tunnel will be located at slate location zone of the Kistinka Suite, whereas the lower (north) part will be located at the Dariali granite massif.

On the left side-hill of the river Tergi gorge, between its left tributaries the Bashi and the Saketseti, on 3 km distance, Lower Jurassic sediments are completely covered with Late Pleistocene Chkheri lava flow Quaternary formations of various genetic type. On the Military Road these igneous rocks are represented by andesitic and andesitic-dacitic lavas alternating with macro-fragmental pyroclasts and tuffs. Alluvial, deluvial-proluvial and colluvial sediments of various content and of great thickness have also developed here.




As was mentioned above, the designed tunnel will be located at slates and Dariali granite maffis of Sinemurian age of the Lower Jurassic Kistinka Suite.

Sinemurian Kistinka suite formations are represented by the southern contact of Dariali granitoid massif, within 1.5 m range. In this area between granites mainly black slates are distributed in which light-colored thin siltstones and 0.2-1.2 m thick gray, often fine, mainly quartz-bearing siltstone strata are located.

Structurally, this suite here represents a monocline with complex structure with a steep tilt to the south at 75-85$^0$. In its approximately mid-part, within 400 m range, it is complicated with a flexure bend of low-angle morphology. The latter is dislocated with highly compressed intense folds, the width of which reaches 100 m. Those with narrow curves and steep wings are located sub-vertically. Their axial planes are tilted to the north at mostly 80-85$^0$. Folding surface is tilted in the same direction, but at 30$^0$. Through the southern wing of the flexure presumably goes a small-range fault with an 80$^0$ tilt to the south.

It should be noted that in Kistinka suite rocks developed in the area between the granites, cleavage distribution is not high. Their narrow (1-5 mm) planes are rarely present in the members of black slates, where they are located parallel to foliation.

To the north from the Kistinka Suite, Dariali Late Paleozoic granite massif is located, the denudations of which continue along the valley for 4 km. In its southern contact, the plane of which is tilted to the south at 80$^0$, mylonitized and schistose granitoids directly, without faulting, contact with Kistinka suite's metamorphic black slate member. The latter is closely stuck and welded to the granites surface. Slaty cleavage planes and the cleavage developed in the slates are parallel to each other within the contact zone. The northern contact of Dariali massive against the contained rocks is tilted to the north at 80-85$^0$. Here black metamorphically altered indurated (hornstoned) and almost massive granites contact with each other directly, without faulting, in which only very weak orientation of their structuring minerals is observed. The slates contained within the contact range, strongly adhere and weld to the granite surface.

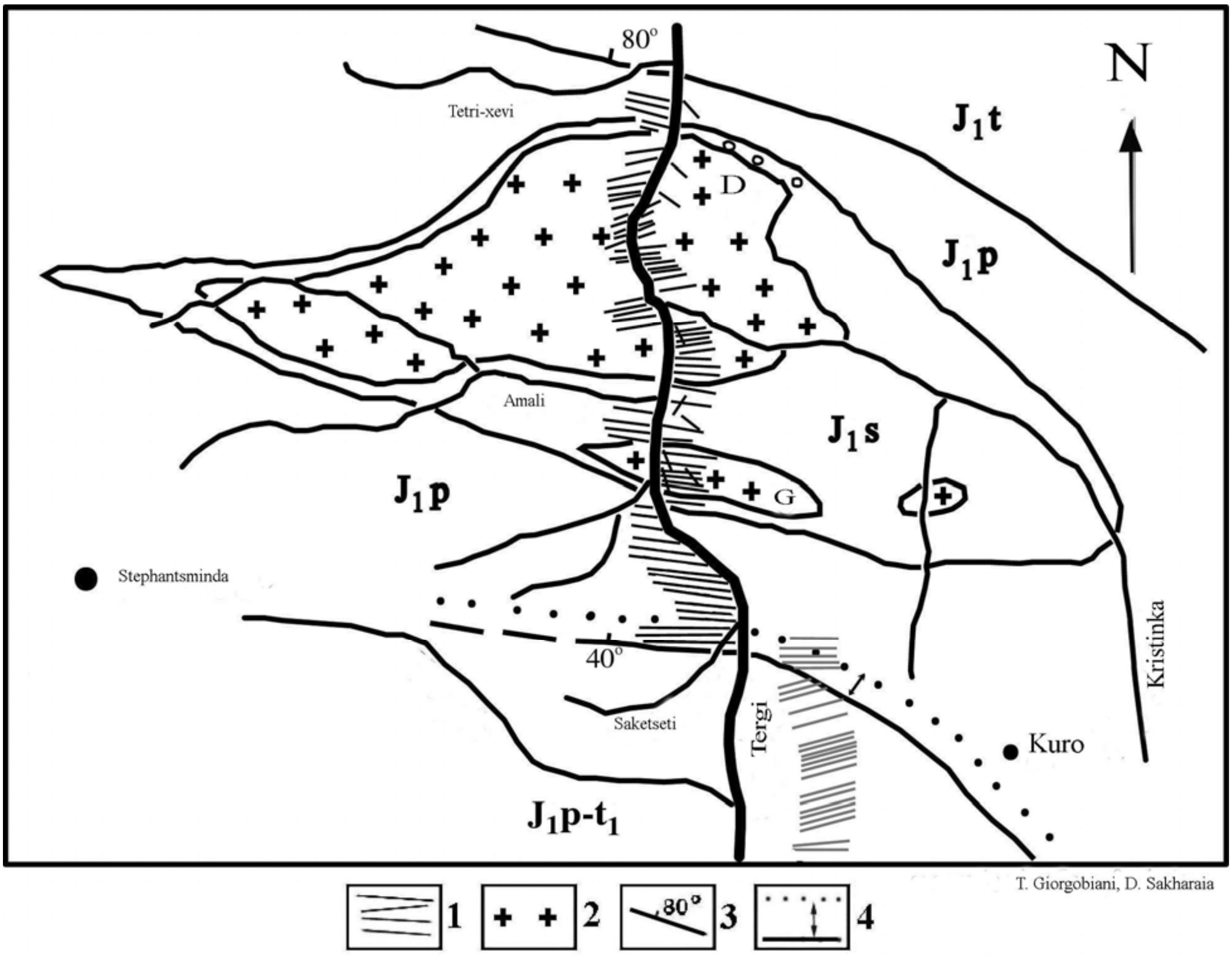
It should be noted that apart from slaty cleavage, faulted structures are developed at some places in Dariali granite mass is with north-western (290-300$^0$) bedding angle. They are everywhere tilted northward at 75-80$^0$ and divide the massive into various-size lengthwise blocks. Their displacements and kinematics remain undefined due to absence of landmarks.

Dariali massive, compared with Gveleti granitoids, has more different inner structure. To the north from its southern contact, along 450 m, sub-vertical slaty cleavage is spread in granitoids, which is observed as an arrangement of its structuring minerals in parallel planes. Besides, within this interval, foliation structures generated by streams and flows are developed in them which is representative of the trace of the constituent substance's plastic movement during crystallization. They are represented by alternation of granite strata having different color, particle grading, composition, texture. The thickness of the flow–generated layers is unequal and varies within wide range: 1-5 cm, 10-50 cm, 1-10 m etc. Granitoids of such facies are not found in much wider central and northern parts of the massive. Moreover, here slaty cleavage in granites disappears and massive, mostly medium-size and coarse, as well as porphyritic granitoids are developed on these sites. Thus, by inner texture Dariali massive represents an asymmetric structure. Here, on a large segment, to its northern border, there are no extreme facies and foliated textures located in the relatively narrow band of the southern contact.

Various thickness diabase dikes are widely spread within Dariali massif. They are shown at the engineering-geological map ans sections (see annexes).

In the river Tergi Gorge, diabase dikes are distributed within the Greater Caucasus Mountain Range zone and the northern edge of Kazbegi-Lagodekhi zone, mainly represented by Sinemurian- Plinsbachian-Lower Toarcian, highly deformed slates. They have also developed within Late Paleozoic Dariali and Gveleti granitoid massive.

Intensely dislocated Lower Jurassic slaty member is pierced with numerous subvertical cleavage planes and viscous and brittle small faults surfaces; and in Dariali granitoids, steep planes of slaty cleavage alternating with massive rock segments are unequally developed. Along these structural elements, mostly diabases are intruded and located creating the main system of dikes. They sometimes cut the cleavage and foliation surfaces, but despite the heavy folding in their constituent sediments, the dikes themselves are not dislocated.




Diabase dikes in Dariali Gorge are characterized by different orientations and in their SN orientations considerable differences are observed. In the Kistinka suites and Gveleti granitoids, diabase bodies with sublatitudinal bedding angles (270-285$^0$) are distributed, with predominantly represented attitudes in this gorge. Orientation of diabase dikes again changes in foliated and massive Dariali granitoids, where their bedding angles again become south-western (240-260$^0$).

Within the distribution ranges of diabase bodies of all types of orientation, transversal diabase dikes with near N-S bedding angles (335-345$^0$) are located, which points to their relatively young age.

In total, within granite massives and in their constituent slates, diabase dikes have developed with SW, NW and near NS bedding angles. Their thicknesses vary within 0.3-8 m, and sometimes reach 10-20 m. The pattern of the dikes is normally steep – 70-85$^0$, sometimes 60$^0$ or 90$^0$, and they are tilted to the south or to the north.

After determining orientetion of diabase dikes represented in Dariali Gorge, it was found that they are cut in the fault systems of different genesis. Diabase dikes distributed in granitoids are mostly located in extensional structures, which belong to dip-slip faults (bodies with S-W and N-W bedding angles), while their small number is developed in strip faults (near N-S dikes) and along the surface of slaty cleavage originated as a result of compression. In the Lower Jurassic metamorphic clay slate members, diabase dikes are mostly located in the cleavage planes which represent flattening fractures, while the rest are intruded in oblique and transversal extensional faults, as well as in viscous and brittle fault zones.

It should be noted, that diabases slightly affect their constituent slates. Contact metamorphism is expressed only by a narrow (from several cm, to the first meter) zone of hornstones on both sides of the dikes, where foliated texture of the constituent rocks is largely altered or completely wiped out.

Thus, all diabase bodies on this segment of the r. Tergi, despite their composition and texture, are only the dikes of intrusive origin and originated after formation of folded structures in the massif.

## 2.4 Fault Tectonics

On the proposed Dariali HPP project, investigations were carried out to identify joint system in rocks. The studied area is located within the axial and southern slope tectonic zones of the Greater Caucasus fold system. The axial zone is represented by alternation of Sinemur slates, sandstones and quartzites intersected by Dariali and Gveleti granitoid masses. The southern ridge zone is represented by alternation of Plinsbachian clay slate and siltstones with rare thin bands of sandstones. Sediments of the both zones are cut by various thickness (0.5-25 m) almost vertical diabase dikes. All types of rocks here are characterized by well-defined rock discontinuity.

For investigation purposes, in different places, different strata and rock types were selected based on their lithological and physical-mechanical properties. A total of 10 spots (outcrops) were identified and 218 measurements made (see Diagrams 1-10). Among these points, those measurements which were made within the Kistinka Suite and granite massif, have been selected for characterization because of their lithological and structural-tectonic originality. Descriptions include their coordinates, lithological description of the rock, geographic position, fault location on rose diagram and Vulff net, their statistical analysis and the list of separate fault measurements.

The obtained data was processed using 2Dmove2.5 software. It is worth of mention, that detailed structural and statistical analysis enabled detailed description of the fault tectonicson the project area (Avalishvili, 1968; Kipiani, 1985).

Based on the general statistical analysis, all faults can be classified as either going parallel to, across or diagonal to the rock layers. There are six primary systems of faults and three main vector components in the area (see Figure 1), also there are some less spread fault systems (VII-XI).

Based on the analysis of data obtained from the fault investigation in the area, the following systems of faults were identified:

I. 24-39°∠4-37°

II. 69-95°∠25-56°

III. 115-140°∠6-89°

IV. 202-230°∠5-36°

V. 237-283°∠25-76°

VI. 312-358°∠16-47°

At some sites, relatively insignificant fault systems were found, such as:

VII. 8-15°∠55-65°

VIII. 150-190°∠16-88°

IX. 295-305°∠25-75°

The main vector component, after averaging, can be expressed in percentage terms, which will allow to break down the system of faults. Faults of the first system make up 6% of all faults (24-39° ∠4-37°), faults of the second system - 7% (69-95° ∠25-56°), the third fault system – 6% (115-140$^0$ ∠6-89°), the fourth fault system - 15% (202-230° ∠5-36°), the fifth fault system – 21% (237-283$^0$ ∠25-76°, and the sixth fault system makes uo 16% (312-358$^0$ ∠16-47°). The main stress tensor (or direction) is N – (0(360)$^0$ ∠82°). All the fault systems are contemporary to the Caucasus upthrust..

It should be also mentioned that less spread faults fall in NW (295-305°) direction with oblique angles (25-75°) cross all the other above mentioned existing fault networks, hence, these are younger than the other ones. Such system of faults mainly originates from compression forces caused by folding at the late-Alpine stage.

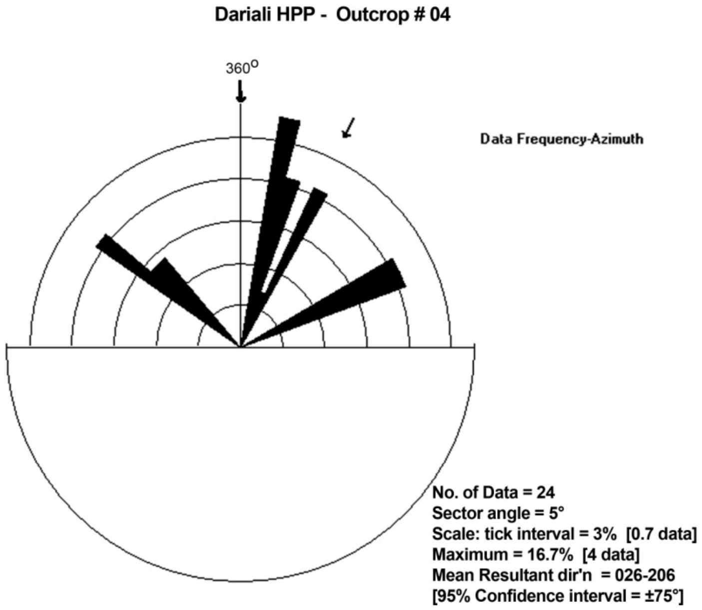
Below are given rock faulting properties according to outcrops.

**Outcrop # 4**

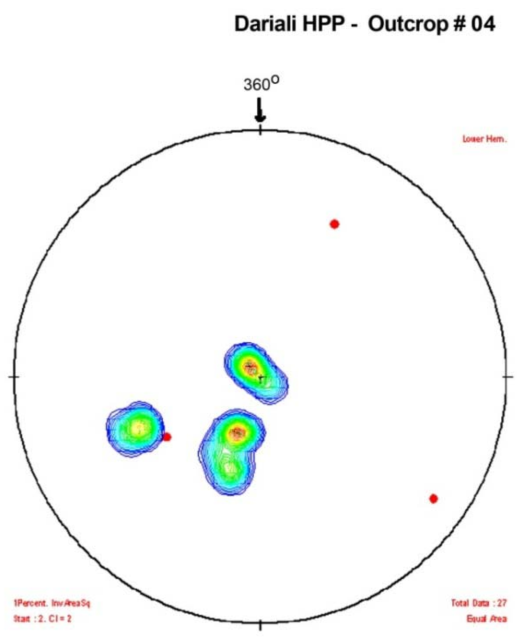
Coordinates: X = 469473 , Y= 4728834
Rock composition:
yPZ3 - Gveleti granitoid massive. Light gray granites and gneiss. Dark gray diabase dikes.

Fault Characteristics

| N | Dip azimuth, degree | Dip angle, degree | N | Dip azimuth, degree | Dip angle, degree | N | Dip azimuth, degree | Dip angle, degree |
|---|---|---|---|---|---|---|---|---|
| 1 | 310 | 82 | 9 | 210 | 65 | 17 | 195 | 70 |
| 2 | 310 | 86 | 10 | 195 | 55 | 18 | 195 | 72 |
| 3 | 320 | 84 | 11 | 195 | 60 | 19 | 245 | 45 |
| 4 | 315 | 88 | 12 | 200 | 70 | 20 | 245 | 48 |
| 5 | 130 | 85 | 13 | 205 | 70 | 21 | 248 | 48 |
| 6 | 140 | 88 | 14 | 200 | 60 | 22 | 250 | 40 |
| 7 | 315 | 85 | 15 | 200 | 55 | 23 | 245 | 40 |
| 8 | 210 | 70 | 16 | 210 | 60 | 24 | 250 | 47 |




Drawing 1. Rose Diagram




**Trend Plunge Type**
**26 32 Eig 1**
**125 15 Eig 2**
**237 53 Eig 3**

Drawing 2. Summary Diagram of the Fault System (red circles indicate basic vectors)

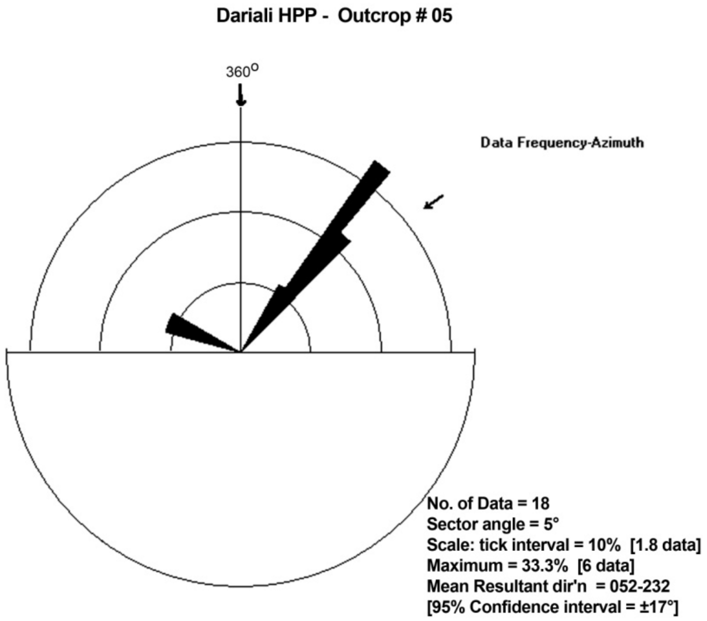
**Outcrop # 5**

Coordinates: X = 469488 , Y= 4729456

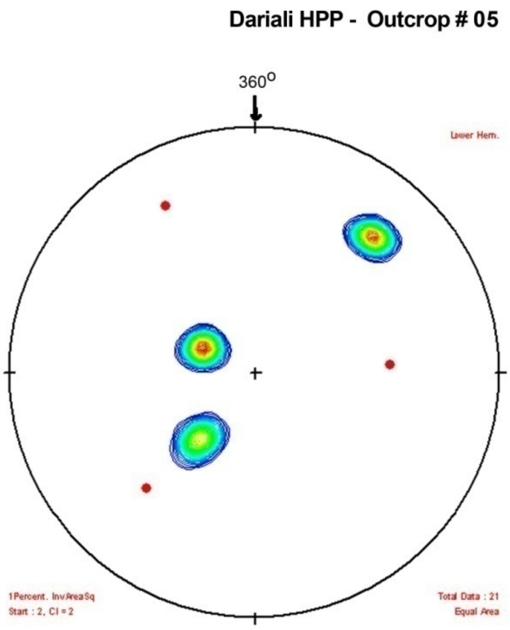
Rock composition: $PZ_3$ – Upper Paleozoic, Kistinka Suite, north contact of Gveleti granitoid massive. Alternation of greenish banbed and grayish banded slates and siltsone.

Fault Characteristics

| N | Dip azimuth, degree | Dip angle, degree | N | Dip azimuth, degree | Dip angle, degree |
|---|---|---|---|---|---|
| 1 | 220 | 60 | 10 | 295 | 75 |
| 2 | 220 | 65 | 11 | 295 | 72 |
| 3 | 215 | 65 | 12 | 300 | 72 |
| 4 | 215 | 60 | 13 | 40 | 26 |
| 5 | 225 | 60 | 14 | 40 | 30 |
| 6 | 220 | 55 | 15 | 38 | 30 |
| 7 | 290 | 70 | 16 | 43 | 25 |
| 8 | 290 | 68 | 17 | 43 | 30 |
| 9 | 300 | 70 | 18 | 43 | 26 |




Drawing 1. Rose Diagram




| Trend | Plunge | Type |
|---|---|---|
| **87** | **44** | **Eig 1** |
| **223** | **36** | **Eig 2** |
| **332** | **24** | **Eig 3** |

Drawing 2. Summary Diagram of the Fault System (red circles indicate basic vectors)

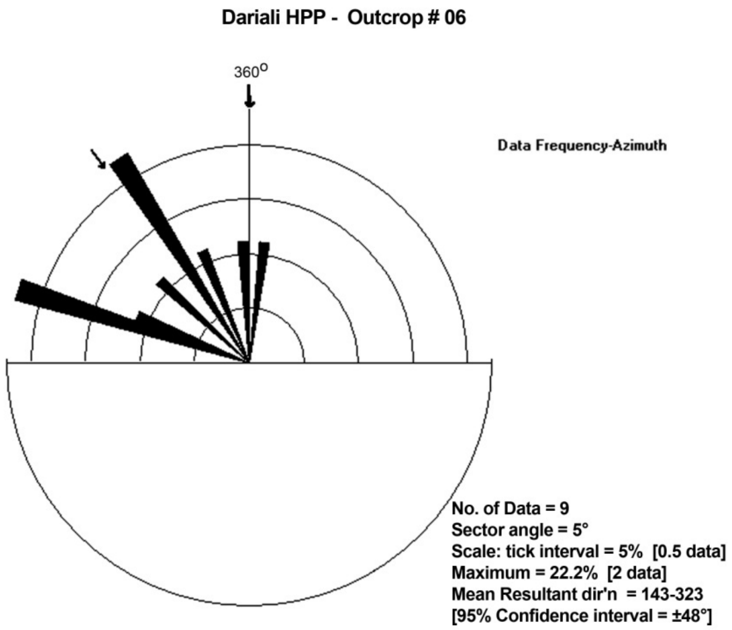
**Outcrop # 6**

Coordinates: X = 469797 , Y= 4730861

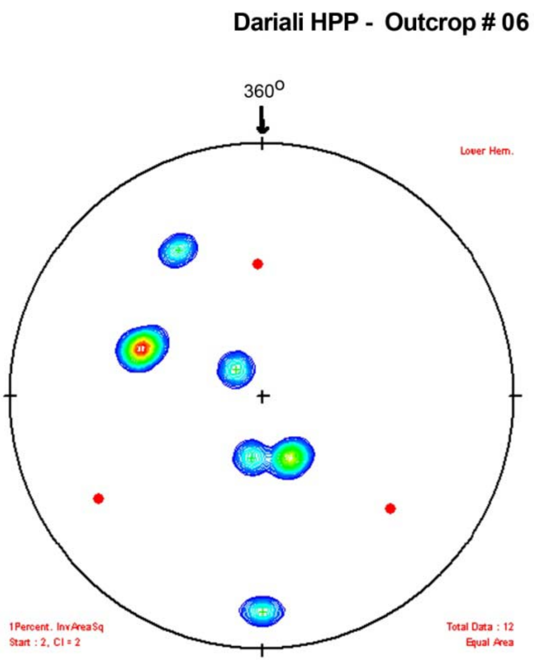
Rock composition: $yPZ_3$ – Dariali granitoid massive. Light gray granites and gneisses. Dark gray diabase dikes.

Fault Characteristics

| N | Dip azimuth, degree | Dip angle, degree | N | Dip azimuth, degree | Dip angle, degree |
|---|---|---|---|---|---|
| 1 | 190 | 70 | 6 | 290 | 48 |
| 2 | 160 | 68 | 7 | 290 | 45 |
| 3 | 315 | 78 | 8 | 150 | 68 |
| 4 | 330 | 34 | 9 | 180 | 16 |
| 5 | 295 | 50 | | | |




Drawing 1. Rose Diagram




| Trend | Plunge | Type |
|---|---|---|
| **131** | **33** | **Eig 1** |
| **358** | **47** | **Eig 2** |
| **238** | **25** | **Eig 3** |

Drawing 2. Summary Diagram of the Fault System (red circles indicate basic vectors)

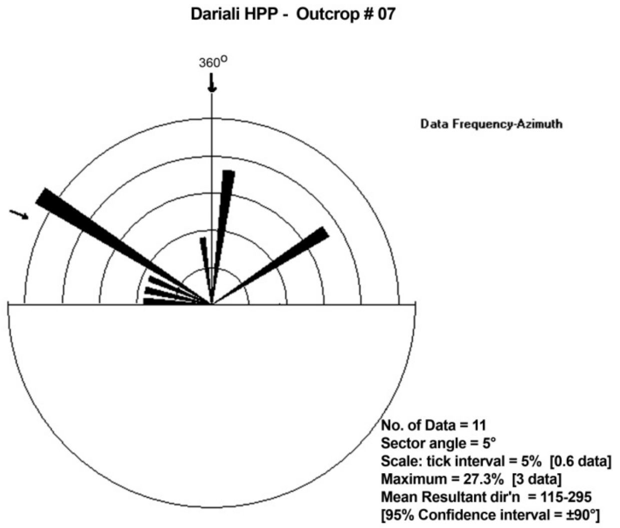
**Outcrop # 7**

Coordinates: X = 469800 , Y= 4730439

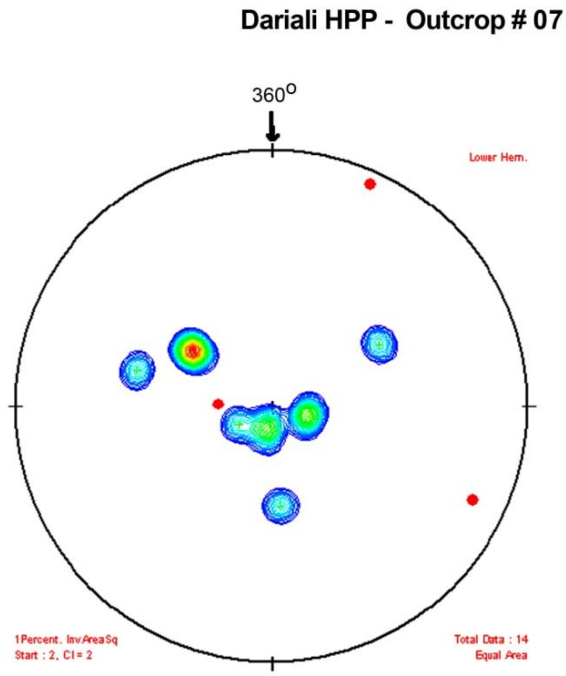
Rock composition: $\gamma PZ_3$ - Dariali granitoid massive. Light gray granites and gneiss. Dark gray diabase dikes.

Fault Characteristics

| N | Dip azimuth, degree | Dip angle, degree | N | Dip azimuth, degree | Dip angle, degree |
|---|---|---|---|---|---|
| 1 | 190 | 80 | 7 | 305 | 58 |
| 2 | 190 | 85 | 8 | 115 | 78 |
| 3 | 305 | 58 | 9 | 60 | 50 |
| 4 | 305 | 62 | 10 | 175 | 58 |
| 5 | 285 | 45 | 11 | 240 | 78 |
| 6 | 95 | 78 | | | |




Drawing 1. Rose Diagram




| Trend | Plunge | Type |
|---|---|---|
| 115 | 15 | Eig 1 |
| 24 | 6 | Eig 2 |
| 272 | 73 | Eig 3 |

Drawing 2. Summary Diagram of the Fault System (red circles indicate basic vectors)

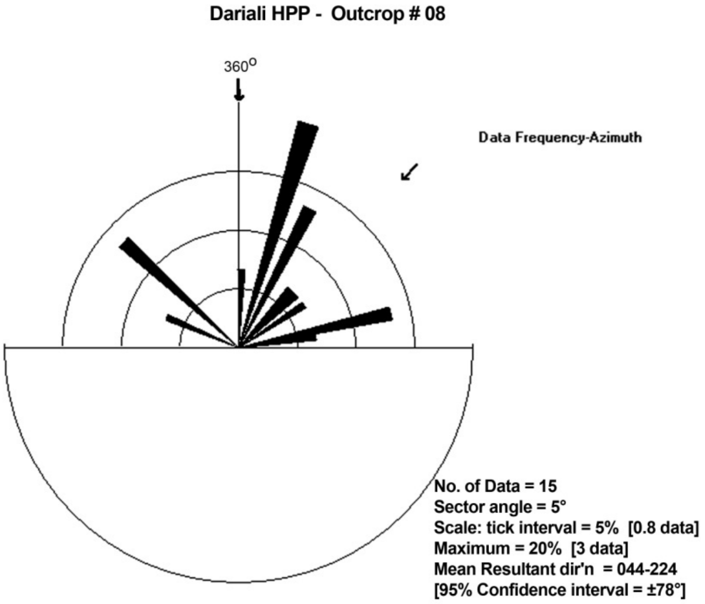
**Outcrop # 8**

Coordinates: X = 469720, Y= 4728337

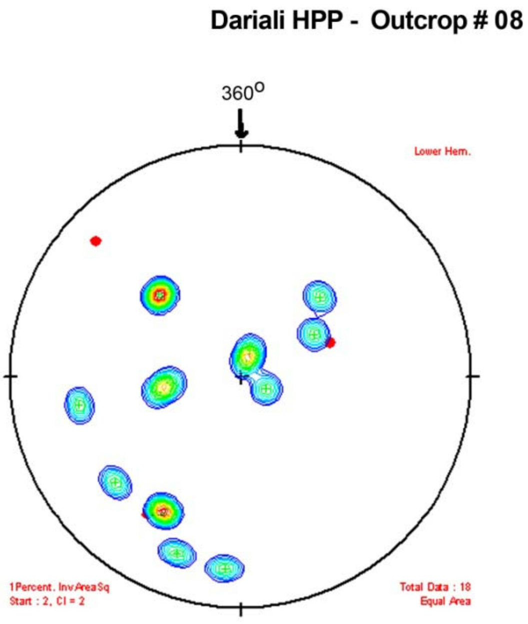
Rock composition: $PZ_3$ - Upper Paleozoic, Kistinka Suite, south contact of Gveleti granitoid massive. Metamorphic slates, quartzite. Diabase dikes.

Fault Characteristics

| N | Dip azimuth, degree | Dip angle, degree | N | Dip azimuth, degree | Dip angle, degree |
|---|---|---|---|---|---|
| 1 | 20 | 80 | 9 | 230 | 30 |
| 2 | 20 | 85 | 10 | 260 | 60 |
| 3 | 260 | 30 | 11 | 265 | 65 |
| 4 | 210 | 32 | 12 | 185 | 18 |
| 5 | 210 | 35 | 13 | 200 | 20 |
| 6 | 115 | 80 | 14 | 45 | 50 |
| 7 | 315 | 48 | 15 | 60 | 60 |
| 8 | 315 | 50 | | | |




Drawing 1. Rose Diagram




| Trend | Plunge | Type |
|---|---|---|
| 69 | 56 | Eig 1 |
| 214 | 29 | Eig 2 |
| 313 | 16 | Eig 3 |

Drawing 2. Summary Diagram of the Fault System (red circles indicate basic vectors)

## 2.5 SEISMIC HAZARD ASSESSMENT OF THE STUDUED AREA

***Study Area***

The area for seismic hazard assessment was selected as longitude from 44.58 to 44.69 and latitude from 42.62 to 42.71 (see fig.1).

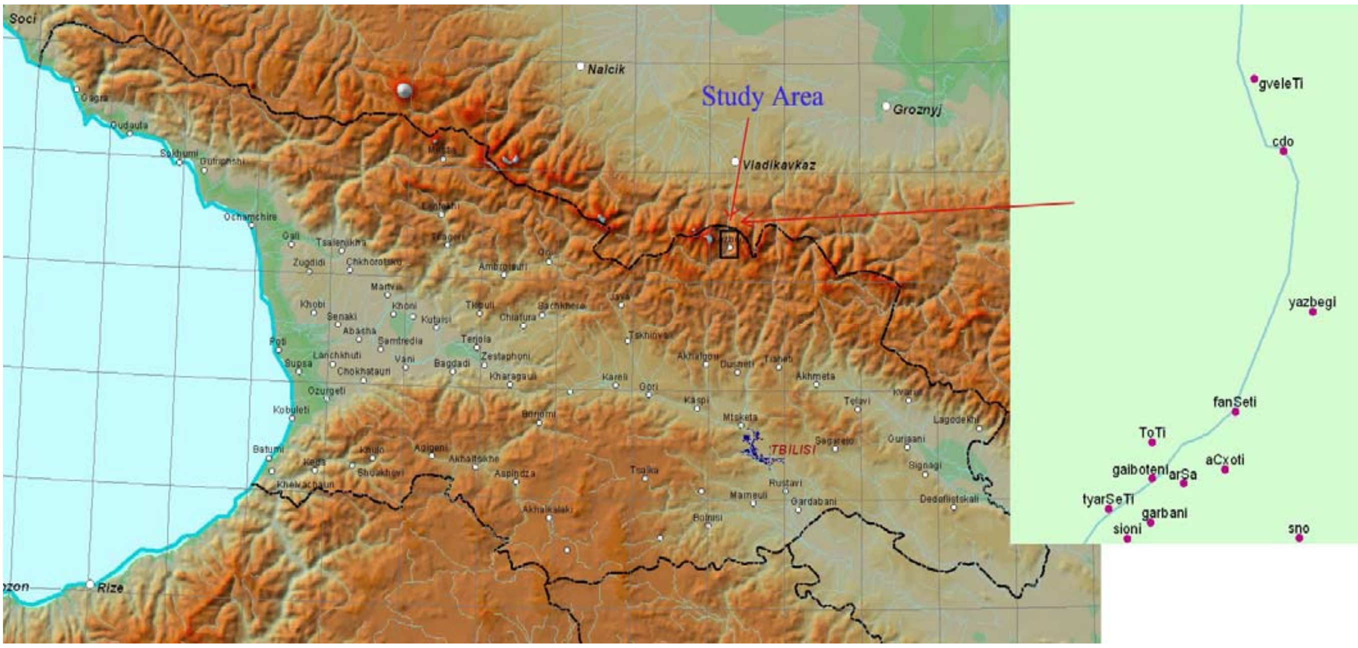



*Fig.1. Study Area.*

***Tectonic Setting***

Georgia is situated in Caucasus. It is one of the most seismically active regions in Alpine-Himalayan collision belt. The analysis of the historical and instrumental seismological shows, that this is the region of moderate seismicity. The strong earthquakes with magnitude up to 7 and macrosiesmic intensity 9 (MSK scale) occurred here. The reoccurrence period of such event is of order $10^3$-$10^4$ years.

The seismicity of the area reflects the general tectonics of the region. The main seismotectonic feature is the junction between Arabian and Eurasian plates. The northern movement and counterclockwise rotation of Arabian plate causes westward movement of Turkish block, eastward movement of Iranian block along the strike-slip faults and the creation of thrust faulting systems in Caucasus. Fault structures in Georgia (Gamkrelidze et al, 1998) exist mainly at the boundaries of tectonic units. The majority of faults were active during the Late Alpine (Orogenic) stage and have been developing till now. The Caucasian northwest and longitudinal faults, oriented along latitudes should be noted from this viewpoint. Several intrazonal faults have the same direction. All these faults are characterized mainly by the prolonged development and were born into different stages of extension of the Caucasus (middle Paleozoic, Early Jurassic, Late Jurassic, Early Cretaceous, Late Cretaceous, Middle Eocene, Late Pliocene) at the margins of the paleostructures of the Caucasus and Transcaucasus: of the island arcs, of the marginal sea of the Greater Caucasus, Atchara-Trialetian intraarc rift. Almost each of longitudinal faults was transformed into the deep reverse fault, thrust fault or tectonic nappe during the Orogenic stage of the Caucasus development, in a process of intense compression of the earth crust. Transverse faults of the Caucasus (submeridional, northeast and northwest) developed lately. Some of them have been developed within the certain large tectonic units (e. g. in the west part of Georgian block) or are strictly through ones (Tskhinvali-Kazbegi fault).

The majority of faults are lateral. Almost each main fault is revealed in different geophysical fields. The most of them are seen in aerial photographs. It was shown by means of the multidisciplinary data, that the fault structures are actually the margins between blocks. The map of active faults of Georgia contributed in current study is shown on Fig. 2.

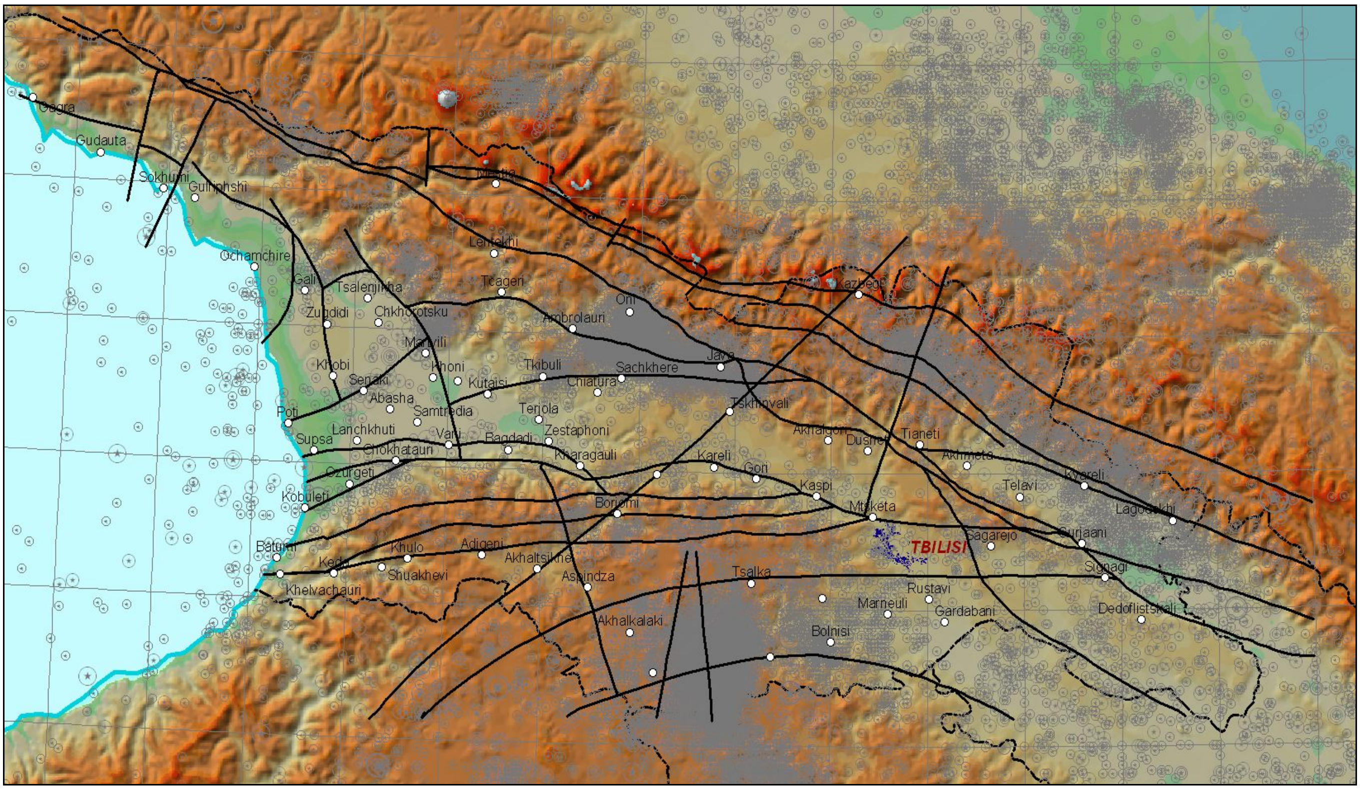



*Fig. 2. Map of active faults (by Gamkrelidze et al. 1998) and epicenters of Georgia*

## I. Hazard Analysis

### Methodology

Cornell approach, namely computer program SEISRISK III after Bender and Perkins 1987, was used for calculations. Seismic effect was calculated for the Peak Ground Acceleration (PGA) (horizontal and vertical). The methodology used in most probabilistic seismic hazard analysis was first defined by Cornell: it consists of four steps (Reiter 1990, Kramer 1997, Musson 1999):

1. ***Definition of earthquake source zones.***
The area under investigation is divided into discrete seismic source zones, each of which deemed to be uniform in the character of its seismicity. There should be an equal probability that an earthquake of a given magnitude could occur at any place within a single source zone.
2. ***Seismicity (definition of recurrence characteristics) of source zones***.
The seismicity within each source zone is studied, using the earthquake catalogue, in order to determine the magnitude-frequency relationships, seismic rate and other parameters.
3. ***Estimation of earthquake effect*** at the site.
A locally appropriate attenuation relationship is chosen, to relate the expected ground motion at site during an earthquake to the magnitude of the earthquake and its distance from site. The uncertainty or scatter of the ground motion values is an important variable, which is essential for the analysis.

## *4.* Determination of hazard at site.

The hazard analysis is based on the fact that the probability that an earthquake of magnitude M occurs in a source zone within any given distance interval is proportional to the fraction of the area of the zone that occurs within this range of the site. Since each source zone is deemed to be homogenous, the fractional occurrences expected in any small sub-area of the zone can easily be calculated. An analytical integration is performed over all ground motion values, magnitudes, and source zones. From the results it is possible to determine the probability of any intensity or acceleration value being exceeded, assuming That seismic process to follow a Poison distribution.

### Data

***Definition of earthquake sources.***

The map of active faults of Georgia after E. Gamkrelidze et al. 1998 was used as a basis for definition of seismic source zones (SSZ). Apart from linear seismic sorces areal one was defined for Javakheti highland, due to its complex nature (completely covered with volcanic deposits) and diffused type of seismicity.

After locating SSZ-es their parameterization was carried out, i.e. for each of them seismic potential $M_{max}$ - the largest possible magnitude was estimated This is the most difficult task in a process of SSZ parameterization. In this work $M_{max}$ was determined using various relations.

The upper limit of $M_{max}$ has been evaluated in the first place. Relationships given in *Varazanashvili 1998* were used for this purpose, since they match regions of moderate seismicity like the Caucasus and Georgia:

The second significant parameter, characterizing SSZ-es is a range of depths at which the most of sources originate. Four zones were distinguished throughout the territory of Georgia: 1) The Greater Caucasus, 2) Intermountain depression, 3) Lesser Caucasus, 4). The Transcaucasian area of transverse elevation passing across the Lesser Caucasus within the limits of Georgia, in the form of Javakheti Plateau. Two ranges of depths can be selected: $\Delta h = 3 - 7$ km ($h_1 = 5$ km) and $\Delta h_2 = 9 - 15$ km ($h_2 = 12$ km). The first range is associated with the relatively small earthquakes M<5, and the second range - with the large ones M≥5. Average value of depth 10 km was used for calculations.

***Definition of recurrence characteristics.***

The seismicity within each source zone was analyzed using the catalogue of earthquakes of Caucasus. The catalogue was checked and revised. Hypocentral parameters of earthquakes in study area were related. This catalogue is up year 2010 and comprises more than 57,000 earthquakes starting from B.C. Among them, 300 events are historical (they occurred before 1900). Catalogue was declustered and revised to obey Poissonian distribution of events.

Seismic rates for each SSZ were estimated for time period 1962-2010 and M>2.5, which is assumed to be completeness threshold of catalogue. Earthquake were assigned to each Fault or Zone to study Gutenberg-Richter relation, taking into account errors in epicenter estimation. Due to leak of detailed data concerning errors in location, average model was taken, assuming that errors are normally distributed with standard deviation equal to 3.4 km-s, distances from each earthquake to all possible SSZ were measured and SSZ-s closer to earthquake for les that three standard deviation were considered only. Based on distances measured weight to each SSZ was assigned based on probability density distribution curve of standard deviation. At the end of procedure assigned weights to each SSZ were scaled (normalized) so that their sum was equal to one; this was done to “split” the earthquake between zones completely. Special program code was written in GIS (ArcView) to apply above described method to all SSZ-s. Obtained frequency-magnitude distribution for each

SSZ was normalized in time and a and b coefficients were estimated using least square approach. Estimated values are given in Table 2.4.1.

***Table 2.4.1*** *- SSZ Parameters*

| NAME | Abbr. | Mmax | A | B |
|---|---|---|---|---|
| Gebi – Lagodekhi | f1 | 7.0 | 3.105 | -0.927 |
| Main thrust of The Greate Caucasus | f2 | 7.0 | 2.315 | -0.738 |
| Frontal overthrust of the Caucasus nappes | f3 | 6.5 | 2.608 | -0.926 |
| Loki – Agdam | f4 | 6.5 | 3.392 | -0.985 |
| Southern marginal of Adjara - Trialeti zone | f5 | 6.5 | 2.172 | -0.748 |
| Gagra – Java | f6 | 7.0 | 1.646 | -0.518 |
| Frontal overthrust of molasse napple | f7 | 5.5 | 1.459 | -0.602 |
| Tbilisi fault | f8 | 5.5 | 0.485 | -0.500 |
| Asa-Aragvi | f9 | 6.5 | 1.439 | -0.662 |
| Northern marginal of Adjara - Trialeti zone | f10 | 7.0 | 2.034 | -0.726 |
| Borjomi-Kazbegi | f11 | 6.5 | 3.160 | -0.942 |
| Javakheti Zone | Jav | 6.5 | 3.405 | -0.913 |

### *Estimation of earthquake effect*

Strong motion instrumental data in Caucasus and adjacent regions allows us to use PGA (horizontal and vertical) attenuation law for seismic hazard analysis. In the study attenuation laws proposed by (Smit et al 2000) and (Ambraseys et al. 1996) were used.

### *Determination of hazard at site*

Cornell approach, namely computer program SEISRISK III after Bender and Perkins 1987, was used for calculations.

Logic Tree approach was used to account for 50 % probability two possible PGA attenuation models. Both PGA (horizontal and vertical) were calculated at test site for a 50 year exposure time and 1 %, 2%, 5%, 7% and 10 % probabilities of exceeding. Hazard curves were constructed for the study area in the range of 1 to 10 % probability (Fig. 3,4) of 50 years expenditure period. The acceleration values in the units of g are given in tables 2.4.2 and 2.4.3.

***Table 2.4.2 – Calculated horizontal Acceleration Values***

| Prob.% | 1 | 2 | 3 | 5 | 7 | **10** |
|---|---|---|---|---|---|---|
| Ambr | 0.12 | 0.11 | 0.1 | 0.09 | 0.08 | **0.07** |
| Smit | 0.11 | 0.1 | 0.09 | 0.08 | 0.07 | **0.06** |
| Aver. | 0.115 | 0.105 | 0.095 | 0.085 | 0.075 | **0.065** |

***Table2.4.3 – Calculated vertical Acceleration Values***

| Prob.% | 1 | 2 | 3 | 5 | 7 | **10** |
|---|---|---|---|---|---|---|
| Ambr | 0.1 | 0.09 | 0.08 | 0.07 | 0.06 | **0.05** |
| Smit | 0.09 | 0.08 | 0.07 | 0.06 | 0.05 | **0.04** |
| Aver. | 0.095 | 0.085 | 0.075 | 0.065 | 0.055 | **0.045** |

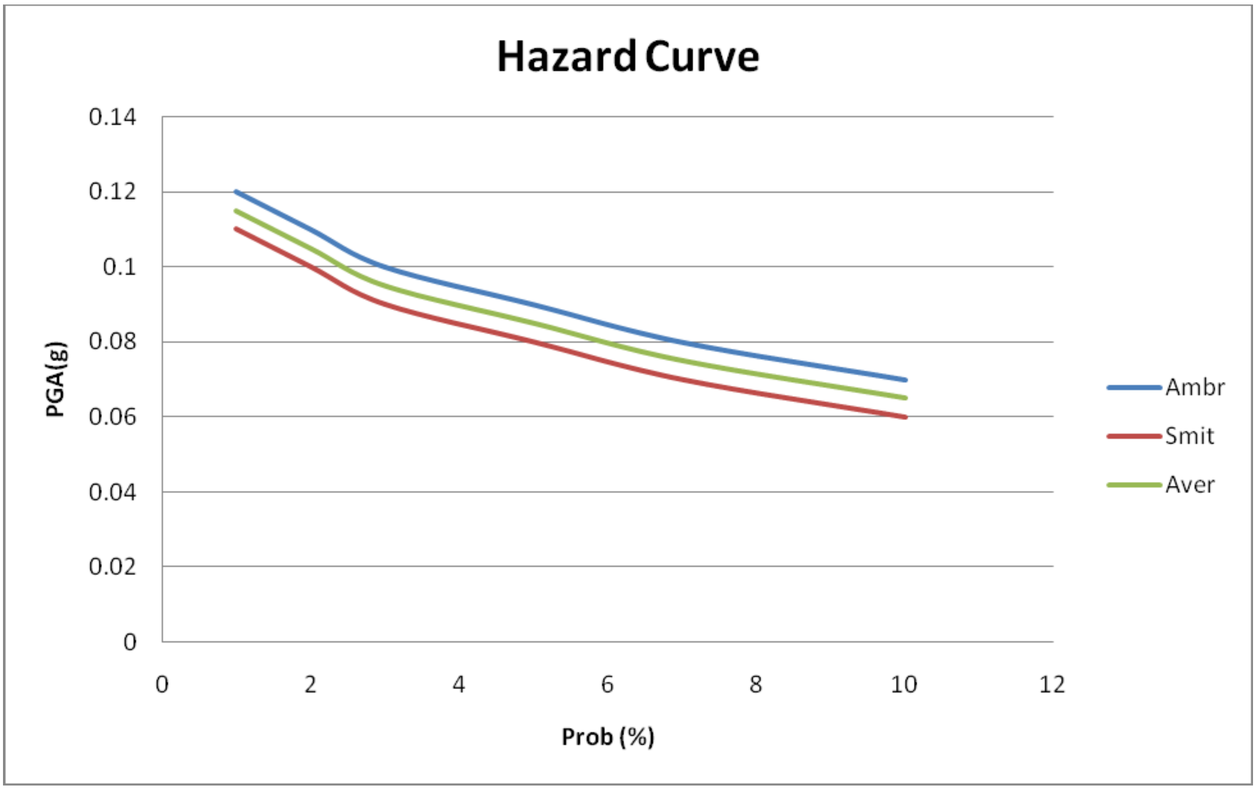



***Fig. 3.*** *Hazard Curves for construction site PGA (horizontal) and different attenuation models.*

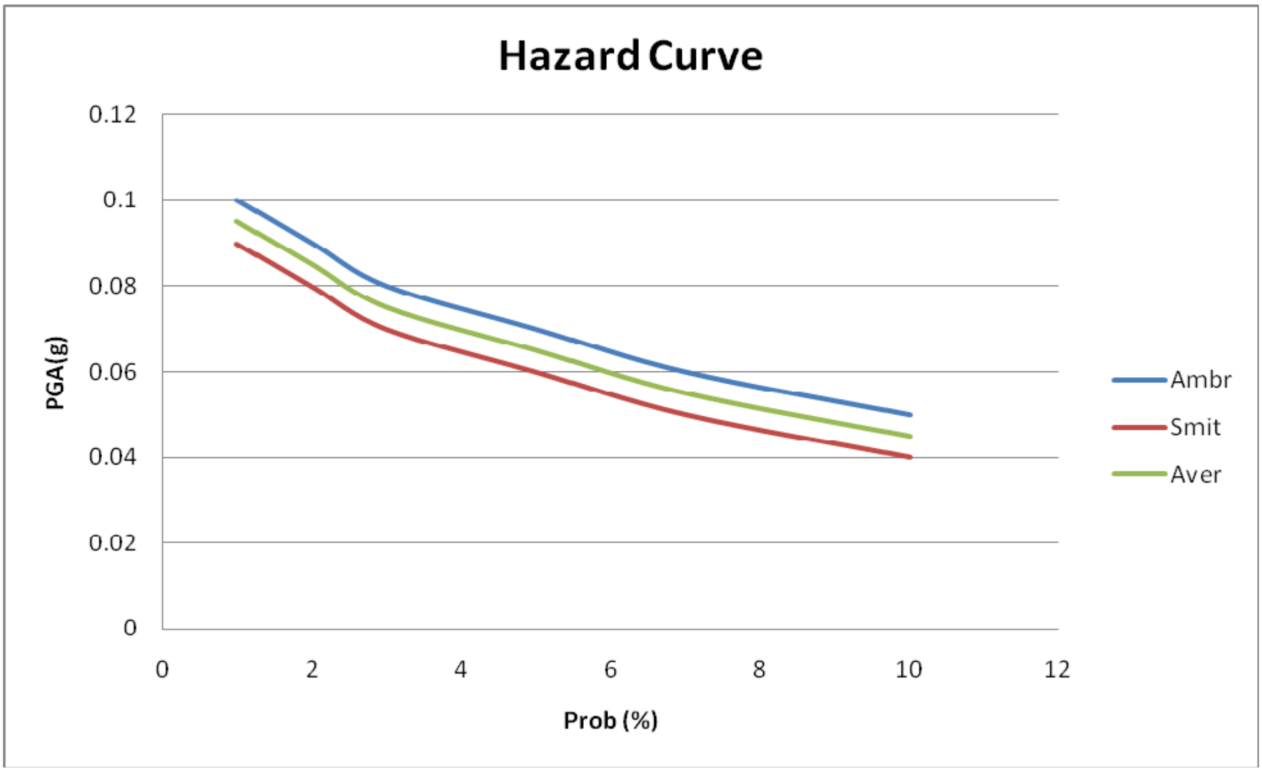



***Fig. 4.*** *Hazard Curves for construction site PGA (vertical) and different attenuation models.*

here has to be mentioned that last columns in tables 2 and 3 calculated for 10% probability coincides to mean return period 475 yrs (table 2.4.4).

***Table 2.4.4– Calculated horizontal and vertical Acceleration Values for 475yrs.***

| Mean return period 475yrs. | horizontal | vertical |
|---|---|---|
| Ambr | 0.07 | 0.05 |
| Smit | 0.06 | 0.04 |
| Aver. | 0.065 | 0.045 |

## 2.6 HYDROGEOLOGIC CONDITIONS

On the location of the motor road, ground waters are of two types according to their circulation: interstitial waters and fracture waters. The former, i.e. interstitial waters are presented in the quaternary colluvial, proluvial and alluvial soils. The other one - fracture waters – is connected to the rock mass and circulates in the fault systems of different genesis which have originated in these rocks. On the project area, interstitial waters are also contained in the fluvio-glacial sediment strata existing on the valley side-hills and bottom. Their thickness, according to the existing outcrops, is sometimes tens of meters, though they are represented as only small fragments in the tunnel location line and adjacent area.

Based on the earlier hydrogeological literary material (Hydrogeology of the USSR, Volume X, Georgian SSR), Lower Jurassic slates, represented on one part of the project area, are sporadically water-encroached. They contain unconfined interstitial waters. The waters are mainly hydrocarbonate-calcium containing, low-mineralized (0.1-0.6g/l). Water inflow to the tunnel is anticipated in the form of dripping, and in large fractures - in the form of frequent dripping and streams. Anticipated water inflow to the bottom hole is 0.02-0.3 $m^3$/hr.

According to the same source, granite mass rocks alternating with slate series also contain unconfined interstitial waters. The waters are mainly hydrocarbonate containing, not often hydrocarbonate-sulphate containing, low-mineralized (0.1-0.4g/l). Water inflow to the tunnel is anticipated in the form of dripping, and in large fractures - in the form of frequent dripping and thin water flowing. Anticipated water inflow to the bottom hole is 0.003-0.4 $m^3$/hr.

A slight seepage at 0.005 l/s (i. e. 18 l/hr) rate occurred in the horizontal borehole of 90 m length drilled during investigation of the Dariali HPP in the Dariali gratine massif, at the location of the designed tunnel line.

Based on the chemical analysis data for the ground water samples taken from boreholes, ground waters are not aggressive against any types of concrete. The environment is medium aggressive against structural steel both, during temporary water-encroachment and below the ground water level, as long as filtration coefficient of practically all varieties of soils and rocks is above 0.1 m per 24 hours.

During construction of derivation tunnels of dariali HPP water occurance was observed mainly in form of slight dripping and dripping. At relatively short sections the dripping was frequent, whereas at the shorter sections both frequent dripping together with water flowing were observed. At the same time, after advancing for some distance, water inflow became less step-by-step because of its decreasing quantity in rock massif at the top of the tunnel, and it inflow was interrupting at all during dry periods. Also, it shall be mentioned that in periods with precipitations water inflow was increased for some short periods of time, in particular from the granite masses because of presence of open fractures in these masses. According to the results of the permanent monitoring of the water inflow, the total water inflow at up to 5 km length section of the derivation tunnel, is 25 lit/sec, that equals to 1500 liters per minute and accordingly to 0.3 liters per minute for 1 long meter of the tunnel, for tunnel with up to 5 m diameter. Less water inflow was observed in the access and tailrace tunnels of the HPP, which rock massif at the top of these tunnels were less since depth of these tunnels from the surface was less. Mainly slight dripping was observed at the whole length of these tunnels.

Based on the above said, water inflow in the tunnel is not expected in quantities which can interfere its construction.

Meantime, it shall be mentioned that frontal inflow of groundwater (within up to 65-70 m distance) was observed in a thick layer of macro-fragmented colluvial-proluvial deposits at the bottom of rock slope located at the south portal of the designed tunnel. The total discharge fo these springs is up to 10 leters per second. Presumably, this water is flowing from the high elevations of the right slope of the gully, then it is running through the gullies bottom, after that it is infiltrated into the slope bottom in the accumulated fine-grained loose soils and comes out along its base (road), in form of frontal inflow.

## 3. SOILS COMPOSITION, STATE AND PHYSICAL-MECHANICAL PROPERTIES

As was mentioned in the introduction of this Report, the main data for description of the geological environment and geotechnical conditions were taken from the engineering-geological investigation of the Dariali HPP construction site, and also from the as-built documentation of the Dariali HPP tunnels, which is based on surveys performed here by GeoEngineering Ltd in 2011-2015 period.

Geotechnically, the soil at the area of motor road tunnel can be divided into two classes: soils with rigid structural links, i.e. rocks, and those without rigid structural links, i.e. earth (soil).

### 3.1 ROCKS

Within the location area of Dariali HPP building structures complex, the rock mass is represented by the following main lithological varieties:

- clay slate with thin siltstones and sandstone bands;
- slate with thin siltstone bands;
- gray, fine arkosic sandstones;
- quartzite;
- greenish tuff sandstone;
- striate greenish and grayish hornstones;
- diabases;

The said strata and bodies of rock lithologies in different parts of the area are given with different alternating combinations and different percentage of mass and volume. Assessment of physical-mechanical properties of individual soil types given in this sub-section, in the next section (Section 4) is followed by assessment of soils conditions for individual projects, based on each soil type's physical-mechanical property values and this assessment is made based on the percentage of a lithological variety of rock in each bench.

From the lithologies soil samples were taken for investigation both, from boreholes (vertical and horizontal), and from denudations. On the denudations samples were taken from shallow boreholes drilled using a portable drilling rig. Sampling spots are shown on the engineering geological map. Investigation results for rock lithologies are given in Table 3.1.

***Table-3.1. Physical-mechanical property values for individual rock lithologies***

| Sequential Number | Name of rock lithology | Density g/cm$^3$ | Uniaxial compression strength, $\sigma_{uc}$ MPa | | Point load strength | | Young's Modulus, E MPa | Poisson's ratio, μ | Rock classification name |
|---|---|---|---|---|---|---|---|---|---|
| | | | Dry | Wet | $Is_{50}$ | $\sigma_{uc}$, MPa | | | |
| 1 | Slate clay with thin siltstone and sandstone bands | 2,70 | 69,81 | 58,93 | 2,65 | 61,32 | 48929 | 0,23 | Very strong rock |
| 2 | Slate with thin siltstone bands | 2,8 | 86,43 | 83,65 | 2,71 | 65.9 | 50108 | 0,19 | Very strong rock |
| 3 | Fine-grained arkosic sandstones | 2,75 | 122,89 | 119,22 | 5,89 | 124,4 | 57872 | 0,20 | Extra strong rock |
| 4 | Quartzite | 2,79 | 151,28 | 139,00 | 7,09 | 162,40 | 27829 | 0,17 | Extra strong rock |
| 5 | Greenish tuff sandstone | 2,63 | 102,50 | 86,45 | 5,01 | 114,86 | 25388 | 0,23 | Very strong rock |
| 6 | Greenish and grayish banded hornstone | 2,84 | 148,46 | 136,51 | 6,66 | 128,37 | 94520 | 0.29 | Extra strong rock |
| 7 | Granites | 2,7 | 112,71 | 109,72 | 3,46 | 88,91 | 76927 | 0,18 | Extra strong rock |
| 8 | Diabases | 2,86 | 109,18 | 94,33 | 4,04 | 102,56 | 58862 | 0,15 | Extra strong rock |

Apart from this, for lithologies of basic rocks, dynamic characteristics (wave propagation velocity, Poisson's ratio, dynamic modulus of elasticity) were defined. Relevant results are given in the table below.

***Table-3.2 Parameter values of dynamic properties of rocks***

| OC # | ρ, gr/cm3 | VP, m/sec | VS, m/sec | Vs/Vp | Coefficient of lateral deformation (Poisson's coefficient) μ | Elastic deformation modulus E, MPa | Description of rocks |
|---|---|---|---|---|---|---|---|
| 1 | 2.70 | 2738 | 1600 | 0.58 | 0.24 | 17147.81 | Clay slates |
| 2 | 2.69 | 2659 | 1640 | 0.62 | 0.19 | 17252.03 | Clay slates |
| 3 | 2.82 | 3712 | 2318 | 0.62 | 0.18 | 35749.28 | Light gray Diabase |
| 4 | 2.70 | 2688 | 1630 | 0.61 | 0.21 | 17332.74 | Clay slates |
| 10 | 2.71 | 2948 | 1925 | 0.65 | 0.13 | 22630.66 | Schist |
| 11 | 2.58 | 2833 | 1643 | 0.58 | 0.25 | 17394.90 | Quartzite |
| 12 | 2.79 | 3887 | 2290 | 0.59 | 0.23 | 36059.18 | Diabase |
| 13 | 2.68 | 3906 | 2180 | 0.56 | 0.27 | 32469.52 | Granite |
| 14 | 2.71 | 3771 | 2400 | 0.64 | 0.16 | 36180.45 | Granite |
| 15 | 2.69 | 3980 | 2520 | 0.63 | 0.17 | 39837.68 | Granite |
| 17 | 2.79 | 4168 | 2830 | 0.68 | 0.07 | 47883.26 | Hornstone |
| 18 | 2.97 | 3702 | 2419 | 0.65 | 0.13 | 39126.83 | Arkosic sandstone |
| 19 | 2.78 | 3011 | 1943 | 0.65 | 0.14 | 23956.56 | Schist |

### 3.2 *SOILS*

Soils, within designed motor road area, are represented by only fragmental uncohesive soils, in which content of fine silty and clayey components is small. Genetically these soils are river bottom alluvial-proluvial ($apQ_{IV}$) and colluvial-proluvial ($cpQ_{IV}$) sediments accumulated at the side-hill bottom. The fragmental material consists of clay slate, slates, granites and diabases. Coarser fractions, angular cobbles, boulders mostly represent diabases and granite fragments in the Tergi river-bed, alluvial sediment contains large amount of subangular boulders. Among Quaternary sediments, in many places on the area also old fluvio-glacial, friable, sediments are found, although the HPP's structures will have practically no contact with these sediments.

Quaternary soil types (under the name "stratum" in the description), are graphically shown on the geotechnical map and sections of the tunnel route location (see Graphical Part).

Below Quaternary soil strata are described.

STRATUM-1 –Boulders with angural gravel and cobbles. The soil is of colluvial-proluvial origin ($cpQ_4$). It is spread in the lower part of the r. Tergi right side-hill, and also at the south portal of the designed tunnel, and represents rock scree accumulated at the bottom of the side-hill with time.

Particle-size distribution could not be performed experimentally due to presence of large quantity of boulders and angural cobbles. However, below is given a particle-size distribution by visual assessment:

- Boulders (>200 mm) ≈ 40%;
- Angular cobbles (200-10mm) ≈ 30%;
- Angular gravel (10-2 mm) ≈ 20%;
- Sandy and clayey fractions ≈ 10%.

According to the density of particles formation, the Stratum-1 is loose at its surface, and is weak and medium dense in depth. The thickness of this stratum was defined by Electrical Vertical Sounding tests at different points, and it is shown on the engineering-geological long section (see Annex 1).

STRATUM-2 – boulders – 40%, cobbles – 35% and gravel - 15%, with sand filler – 10%, dense.Diameter of individual boulders is 2-3 m ($aQ_4$). The soil is of aluvial-proluvial origin ($apQ_4$). It is spread in the r. Tergi river-bed adjacent line. The stratum has various thickness.

Laboratory testing results for stratum samples taken from borholes are given in Tables 3.3 and 3.4.

***Table 3.3. Stratum-2 Prticle-size distribution***

| Sequential # | Borehole # | Sampling depth interval, m | Fraction content in stratum, % | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Boulder >200.0 | Cobbles 200.0-63.0 | Gravel 63,0-2,0 | Sand | | | Silt 0,04 - 0,002 | Clay < 0,002 |
| | | | | | | Coarse 1,18-0,600 | Medium 0,425-0,212 | Fine 0,150-0,063 | | |
| 1 | 5 | 5.0-6.0 | 5,1 | 36,6 | 33,4 | 2,1 | 3,1 | 5,8 | 12,1 | 1,8 |

*Table-3.4. Stratum-2 physical properties*

| Sequential # | Borehole # | Sampling depth interval, m | Moisture content, W% | | Plasticity | | | Consistency index, IL | Density, g/cm$^3$ | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Natural | Semavsebelis | Liquid limit, WL% | Plastic limit,, Wp% | Plasticity number Ip | | Mineral parts $\rho_s$ | Bulk, $\rho$ |
| 1 | 5 | 5.0-6.0 | 10,9 | 14,2 | 28,0 | 20,9 | 7,1 | -0,94 | 2,65 | 1,90 |

It is clear, that particle size analysis does not include content of large subangular boulders and cobbles in the alluvial soil mass. It only shows the ratio of relatively small fractions existing between the boulders. Final description of the stratum (boulder – 40%, cobbles – 35%, gravel -15%, sand – 10%), besides this particle size analysis data, is based on the field visual inspection data as well, conducted during engineering survey. This allowed us to approximately assess particle size distribution in Stratum-2. This stratum of alluvial soil is moist up to the river level, and water-saturated below the river level.

Based on the particle size distribution data given in Table 3.2.1, Stratum-1 on average contains 37% angular cobbles, 32% angular gravel, 15% cobbles. Filler material of these fractions is silty sand. By its physical properties the filler is of hard consistency. According to SPT conducted in the stratum (results are given in lithological columns of boreholes – Annex-1), the soil is dense, as number of B+C blows is within the range from 30 to 50. Natural moisture content varies between 3 and 10%, which means that its moisture content is low.

<u>STRATUM-3</u> – cobbles – 40%, gravel - 20%, boulder – 15-20%, with slightly cemented silty sand/intermediately plastic clay filler – 20-25%. The soil is of fluvio-glacial origin (fg$Q_4$). It is exposed in many places on the side-hill, however, it can be observed at the north portal of the designed tunnel line. At some places it could be revealed under the Stratum-1. As long as the Stratum-3 did not reveal in any of the boreholes during investigation works, no sample was taken and its properties were not studied. Its composition and state is described based on field empirical observations and assessment.

# 4. GEOTECHNICAL CONDITIONS

## 4.1.1 Lithological conditions

Detailed description of the geological structure and lithology of the motor road tunnel location is given in 2.3.3, and graphically shown on the appropriate drawings. According to the description, in the geological structure of the tunnel 2 lithostratigraphic units are distinguished. In the lithostratigraphic units 6 lithologies were registered and investigated. Their list and investigation results are given above (item 3.1, Table- 3.1.1).

Lithological units found on the location of the motor road tunnel, their distribution ranges in the tunnel by stations and percentage of lithologies in each of them are given in the tables below.

***Table-4.1 Lithostratigraphic units, their distribution ranges within the motor road tunnel and percentage of lithologies***

| Sequential # | Stratigraphic identity | Lithological composition | Distribution range of a lithostratigraphical unit form pk+ to pk+ of the ROW | |
|---|---|---|---|---|
| | | | Tunnel Option I | Tunnel Option II |
| 1 | $J_1S$ – Lower Jurassic, Sinemurian. Kistinka Suite Lower part | Black slate with thin siltstone bands, with gray fine arkosic sandstone (0.2-1.2m), whitish quartzite (1-3m), greenish tuff sandstone interbeds (4-10m). Diabase dikes<br>– slate -47%,<br>– arkosic sandstone -20%,<br>– quartzite - 9.9%,<br>– tuff sandstone -19%,<br>– diabase -4.1% | 0+00–3+39 | 0+00–4+51 |
| 2 | $\gamma Pz_3$ - Upper Paleozoic, Dariali Granite Massive | Granitoids, milonitized and schistose, with diabase dikes<br>– granitoid - 90.8%,<br>– diabase - 9.2% | 3+39–11+00 | 4+51–12+00 |

Based on the data shown in Tables 3.1.1 and 4.1, density and strength characteristics of individual lithostratigraphic units were calculated, taking into account the ratio of lithologies in each. Calculation results are given in Table 4.3.2 below.

*Table-4.2 Calculation results for density and strength parameters of individual lithostratigraphic units*

<table>
<tr><th rowspan="3">Sequential #</th><th rowspan="3">Lithostratigraphic Unit</th><th colspan="7">Physical-mechanical property factors of rocks and their weighted average values</th></tr>
<tr><th rowspan="2">Rock name</th><th colspan="2" rowspan="2">Density ρ, g/cm3</th><th colspan="4">Uniaxial compression strength, $\sigma_{uc}$, MPa</th></tr>
<tr><th colspan="2">Natural</th><th colspan="2">Wet</th></tr>
<tr><td rowspan="6">1</td><td rowspan="6">2.2 $J_1S$ - Lower Jurassic, Sinemurian. Kistinka Suite. Black clay slate, with thin siltstone bands, gray fine sandstone (0.2-1.2m), whitish quartzite (1-4m), greenish tuff sandstone interbeds (5-20m), with diabase dikes. Slate with thin bands -47%, arkosic sandstone -20%, quartzite- 9.9%, tuff sandstone -19%, diabase-4.1%</td><td>slate</td><td>2,8</td><td rowspan="6">2,76</td><td>86,43</td><td rowspan="6">104,13</td><td>83,65</td><td rowspan="6">97,21</td></tr>
<tr><td>arkosic sandstone</td><td>2,75</td><td>122,9</td><td>119,2</td></tr>
<tr><td>quartzite</td><td>2,79</td><td>151,3</td><td>139</td></tr>
<tr><td>tuff sandstone</td><td>2,63</td><td>102,5</td><td>86,45</td></tr>
<tr><td>diabase</td><td>2,86</td><td>109,2</td><td>94,33</td></tr>
<tr><td>diabase</td><td>2,86</td><td>109,2</td><td>94,33</td></tr>
<tr><td rowspan="2">5</td><td rowspan="2">$yPz_3$ - Upper Paleozoic, Dariali Granite Massive, milonitized and schistose granitoid with diabase dikes. Granitoid - 90.8%, diabase - 9.2%</td><td>granitoid</td><td>2,7</td><td rowspan="2">2,71</td><td>112,7</td><td rowspan="2">112,39</td><td>109,7</td><td rowspan="2">108,30</td></tr>
<tr><td>diabase</td><td>2,86</td><td>109,2</td><td>94,33</td></tr>
</table>

## 4.2 Geodynamic conditions

In the first place, in terms of geodynamic, a very, and sometimes catastrophic mudflows (which occur here periodically), shall be noted at the riv. Devdoraki site. These mudflows are coming from steep slopes of the mountain glacier (Kazbegi) and that is why it was intended to build a motor road here.

Within the tunnel location, geodynamic condition is worth of attention at the portal sites. In these terms, heavy gradient of the rocky side-hills above both portals should be noted. Worth of particular attention is the northern portal, which will be located directly at the bottom of the high and steep side-hill. Prior to commencement of construction, the side-hill will require clearing from landslide boulders; safety nets or other means should be used in order to provide for workplace safety, both during construction and operation periods. Similar situation is observed on the southern portal as well, and above it, in old erosion gulley, there are fragmented rock material accumulated. Most of this materials represents coarse boulders. The surface part of these fragmented material is loose and can be moved time after time. Therefore, it will be necessary to take protective measures for the portal here.

Also, at the southern portal, certain hazard is posed by the above dry gulleys in which temporary water flows run during heavy rains and snow melting. It will be required to regulate and stabilize the channels of these gulleys, in order to protect the tunnel portal during construction and operation.

Apart from the above said, water infiltrated from the upper part of the slope is permanently inflows into the accumulated colluvial-proluvial soils (Stratum-1) at the bottom of the same gulleys. Water discharge is 10 liters per second. It will be necessary to collect these springs and drain them away in an organized manner.

## 4.3 Rocks discontinuity

Results of rocks discontinuity study were discussed above in 2.4. Discontinuity was investigated along the whole area of rocks distribution. The investigation covers all lithologies and lithostratigraphic units. The investigation results were processed using 2Dmove2.5 application software, diagrams were prepared and quantitative parameters of discontinuity were evaluated. The obtained results are shown on the engineering geological long section of the designed motor road tunnel (see Annexes).

### 4.3.1 Permeability of rocks

As it was mentioned in the hydrogeological section of the report, frontal inflow of groundwater (within up to 65-70 m distance) was observed in a thick layer of macro-fragmented colluvial-proluvial deposits at the bottom of rock slope located at the south portal of the designed tunnel. The total discharge fo these springs is up to 10 leters per second. Presumably, this water is flowing from the high elevations of the right slope of the gully, then it is running through the gullies bottom, after that it is infiltrated into the slope bottom in the accumulated fine-grained loose soils and comes out along its base (road), in form of frontal inflow. Collection of this groundwater and its drainage from the site in a proper manner shall be considered in the design of the south portal of the tunnel.

### 4.3.2 Nature of water show during tunnel laying

Hydrogeological conditions of the tunnel location were discussed in general above, in item 2.6. Here we give forecast assessment of water show based on the information obtained from investigations and literature on rock discontinuity, ground water table on the area and in the horizontal borehole, chemistry of waters and other factors. In general, in the tunnel, mainly nonartesian fracture waters will show, though temporary show of low-head artesian water was observed at small areas at the local sites during construction of the Dariali HPP derivation tunnel. The forecast surge of water is assessed based on the mentioned factors on several different segments. The information is given in a tabulated format, showing stations of the tunnel ROW.

| Massive structure designation | Water type and mineralization g/l | Character of water inflow in the tunnel | Water output per 1 running meter of tunnel, l/s | tunnel segment from pk+m to pk+m |
|---|---|---|---|---|
| Sinemuriam monocline with flexural bend ($J_1s$) | bicarbonate and calcium- containing, 0.1-0.6 | Dripping, occasionally heavy dripping with slight inflows | 0.2–4 | 0+00–3+35 |
| Dariali granite massive, schistose, with subvertical foliation ($\gamma Pz_3$) | bicarbonate- containing 0.1-0.4 | Slight dripping. Heavy dripping at some short sections. | 0.05–0.1 | 3.35–10+63 |

On the small segments of the tunnel, where it crosses large tectonic faults, water inflow is expected in the form of frequent dripping and thin streams. Presumable places of such faults are shown on the engineerin-geological map and on the tunnel's engineering-geological sections.

### 4.3.3 Temperature conditions

In order to specify the geothermal gradient in the proposed tunnel area, temperature measurements were made in the horizontal borehole, as a result of which temperatures at the depths of 19 and 90 meters were 6.6288$^0$C and 7.4022$^0$C respectively. The temperature gradient calculated based on this data is as follows:

$$gradT=(7.4022-6.6288)/\Delta H=0.7734/71=0.01089$$

The maximum expected temperature in the proposed tunnel was calculated from the equation:

$$T=T_{90}+\Delta H \bullet gradT$$

Temperature calculations for different tunnel depths are given below:

| Tunnel location depth, m | Reading depth | ΔH | Measured temperature | Reading-based temperature gradient | Assumed temperature t, degree |
|---|---|---|---|---|---|
| 100 | 90 | 10 | 7,40216 | 0,010892394 | 7,51 |
| 150 | 90 | 60 | 7,40216 | 0,009336338 | 7,96 |
| 200 | 90 | 110 | 7,40216 | 0,009336338 | 8,43 |
| 250 | 90 | 160 | 7,40216 | 0,009336338 | 8,90 |
| 300 | 90 | 210 | 7,40216 | 0,009336338 | 9,36 |
| 350 | 90 | 260 | 7,40216 | 0,009336338 | 9,83 |
| 400 | 90 | 310 | 7,40216 | 0,009336338 | 10,30 |
| 450 | 90 | 360 | 7,40216 | 0,009336338 | 10,76 |
| 500 | 90 | 410 | 7,40216 | 0,009336338 | 11,23 |
| 550 | 90 | 460 | 7,40216 | 0,009336338 | 11,70 |
| 600 | 90 | 510 | 7,40216 | 0,009336338 | 12,16 |
| 650 | 90 | 560 | 7,40216 | 0,009336338 | 12,63 |
| 700 | 90 | 610 | 7,40216 | 0,009336338 | 13,10 |
| 750 | 90 | 660 | 7,40216 | 0,009336338 | 13,56 |
| 800 | 90 | 710 | 7,40216 | 0,009336338 | 14,03 |

| Tunnel location depth, m | Reading depth | ΔH | Measured temperature | Reading-based temperature gradient | Assumed temperature t, degree |
|---|---|---|---|---|---|
| 850 | 90 | 760 | 7,40216 | 0,009336338 | 14,50 |
| 900 | 90 | 810 | 7,40216 | 0,009336338 | 14,96 |
| 950 | 90 | 860 | 7,40216 | 0,009336338 | 15,43 |
| 1000 | 90 | 910 | 7,40216 | 0,010892394 | 17,31 |

#### 4.3.4 Gas show in rocks

No asphyxiant, flameable or other type of gas show was noticed along the whole length (5 km) of the Dariali HPP diversion tunnel and including appropriate sections of the designed motor road tunnel. Therefore, occurance of harmful gases during construction of the motor road tunnel is not expected.

#### 4.3.5 Assessment and classification of rock mass

Based on the rock mass geological structure type, rock discontinuity characteristics (number of fault systems, roughness, filler, water inflow character), uniaxial compression strength value, rock quality designation index (RQD), character of the main structures orientation versus tunnel axis, etc., rock mass rating was classified for the tunnel construction. Assessment of the rock rating was performed by analogy with as-built documentation of the Dariali HPP tunnels, within appropriate formation of rocks.

Along the designed motor road tunnel, rock mass classification components vary and for individual segments different RMR values were obtained. The obtained results for different options are given in Table 4.3 and Table 4.4 below.

*Table-4.3 Rock mass rating for tunnel option I*

| Tunnel Section | Litho-stratigraphical unit (Suite) | Rock Mass Rating | |
|---|---|---|---|
| | | Q | Class |
| pk 0+00 ÷ pk 0+63 | $cpQ_{IV}$ | - | - |
| pk 0+63÷ pk 1+46 | $J_1s$ | 11-18-75% | Rock class B (good) |
| | | 4-9-15% | Rock class C (fair) |
| | | 1-2-10% | Rock class D (poor) |
| pk 1+46 ÷ pk 1+52 | | 1-2 | Rock class D (poor) |
| pk 1+52 ÷ pk 3+34 | | 16-22-89% | Rock class B (good) |
| | | 6-10-6% | Rock class C (fair) |
| | | 1-2-5% | Rock class D (poor) |
| pk 3+34 ÷ pk 3+39 | | 1-2 | Rock class D (poor) |
| pk 3+39 ÷ pk 4+38 | $yPz_3$ | 14-34 | Rock class B (good) |
| pk 4+38 ÷ pk 4+44 | | 1-2 | Rock class D (poor) |
| pk 4+44 ÷ pk 4+56 | | 16-32 | Rock class B (good) |
| pk 4+56 ÷ pk 4+62 | | 1-2 | Rock class D (poor) |
| pk 4+62 ÷ pk 5+01 | | 19-26 | Rock class B (good) |
| pk 5+01 ÷ pk 5+07 | | 1-2 | Rock class D (poor) |
| pk 5+07 ÷ pk 6+38 | | 18-26 | Rock class B (good) |
| pk 6+38 ÷ pk 6+49 | | 1-2 | Rock class D (poor) |
| pk 6+49 ÷ pk 7+34 | | 16-40 | Rock class B (good) |
| pk 7+34 ÷ pk 7+87 | | 8-9 | Rock class C (fair) |
| pk 7+87 ÷ pk 7+92 | | 1-2 | Rock class D (poor) |
| pk 7+92 ÷ pk 9+16 | | 16-18 | Rock class B (good) |
| pk 9+16 ÷ pk 9+22 | | 1-2 | Rock class D (poor) |
| pk 9+22 ÷ pk 9+54 | | 16-18 | Rock class B (good) |
| pk 9+54 ÷ pk 9+60 | | 1-2 | Rock class D (poor) |
| pk 9+60 ÷ pk 9+72 | | 16-18 | Rock class B (good) |
| pk 9+72 ÷ pk 9+78 | | 1-2 | Rock class D (poor) |
| pk 9+78 ÷ pk 11+00 | | 16-18 | Rock class B (good) |

***Table-4.4 Rock mass rating for tunnel option II***

| Tunnel Section | Litho-stratigraphical unit (Suite) | Rock Mass Rating | |
|---|---|---|---|
| | | Q | Class |
| pk 0+00 ÷ pk 0+24 | $cpQ_{IV}$ | - | - |
| pk 0+24 ÷ pk 1+65 | $J_1s$ | 11-18-75% | Rock class B (good) |
| | | 4-9-15% | Rock class C (fair) |
| | | 1-2-10% | Rock class D (poor) |
| pk 1+65 ÷ pk 1+73 | | 1-2 | Rock class D (poor) |
| pk 1+73 ÷ pk 4+45 | | 16-22-89% | Rock class B (good) |
| | | 6-10-6% | Rock class C (fair) |
| | | 1-2-5% | Rock class D (poor) |
| pk 4+45 ÷ pk 4+51 | | 1-2 | Rock class D (poor) |
| pk 4+51 ÷ pk 4+92 | $yPz_3$ | 14-34 | Rock class B (good) |
| pk 4+92 ÷ pk 4+98 | | 1-2 | Rock class D (poor) |
| pk 4+98 ÷ pk 5+64 | | 16-32 | Rock class B (good) |
| pk 5+64 ÷ pk 5+69 | | 1-2 | Rock class D (poor) |
| pk 5+69 ÷ pk 6+14 | | 19-26 | Rock class B (good) |
| pk 6+14 ÷ pk 6+19 | | 1-2 | Rock class D (poor) |
| pk 6+19 ÷ pk 7+62 | | 18-26 | Rock class B (good) |

| Tunnel Section | Litho-stratigraphical unit (Suite) | Rock Mass Rating | |
|---|---|---|---|
| | | Q | Class |
| pk 7+62 ÷ pk 7+72 | | 1-2 | Rock class D (poor) |
| pk 7+72 ÷ pk 8+59 | | 16-40 | Rock class B (good) |
| pk 8+59 ÷ pk 9+13 | | 8-9 | Rock class C (fair) |
| pk 9+13 ÷ pk 9+18 | | 1-2 | Rock class D (poor) |
| pk 9+18 ÷ pk 10+43 | | 16-18 | Rock class B (good) |
| pk 10+43 ÷ pk 10+48 | | 1-2 | Rock class D (poor) |
| pk 10+48 ÷ pk 10+78 | | 16-18 | Rock class B (good) |
| pk 10+78 ÷ pk 10+83 | | 1-2 | Rock class D (poor) |
| pk 10+83 ÷ pk 11+08 | | 16-18 | Rock class B (good) |
| pk 11+08 ÷ pk 11+17 | | 1-2 | Rock class D (poor) |
| pk 11+17 ÷ pk 12+00 | | 16-18 | Rock class B (good) |

## 5. CONCLUSIONS AND RECOMMENDATIONS

5.1 The road tunnel is to be located in the segment of Darial Gorge where the r. Devdorak of mudflow nature joins it. The great destructive force of the mudflow and large amount of transported coarse material cause the necessity for protection of the motor road on the right bank of the gorge by means of transferring its about 1 km-long segment into the tunnel;

5.2 In terms of lithology, the tunnel construction site is structured with rocks over which there are located colluvial-proluvial formations screed at the slope bases, while at its bottom there are alluvial-proluvial Quaternary sediments of the r. Terek and the r. Devdorak. All the strata of the Quaternary cover represent coarse angular boulders and rounded boulders/cobbles;

5.3 On the tunnel's southern portal site, there is a thick plume of colluvial-proluvial coarse soil with large boulder content from which groundwater flows frontally along the road. The sources are nourished from the deeply cut down gullies in the upper part of the slope. The project for arrangement of this portal should envisage groundwater drainage actions. The portal should also be protected against the hazard of loose angular boulders/cobbles falling;

5.4 The northern portal of the tunnel is located at the base of a steep, about $70^0$ rock slope. The rocks on the slope are jointed which creates danger of falling of certain rock masses and individual boulders. Before the construction of the tunnel starts, the slope should be cleared of unstable blocks and actions should be taken to provide for their stability;

5.5 According to hydrogeological conditions, within a certain segment adjacent to the southern portal, greater water inflow may occur in the tunnel compared with the northern segment which will be due to inundation of the colluvial-proluvial plume existing above the tunnel portal with water streams running from the upper part of the slopes. In this part of the tunnel water ingress is expected in the form of frequent dripping inflows (jets), whereas dripping or frequent dripping is expected at the remaining part of the tunnel;

5.6 Show of unhealthy or explosive gases in the tunnel is not expected;

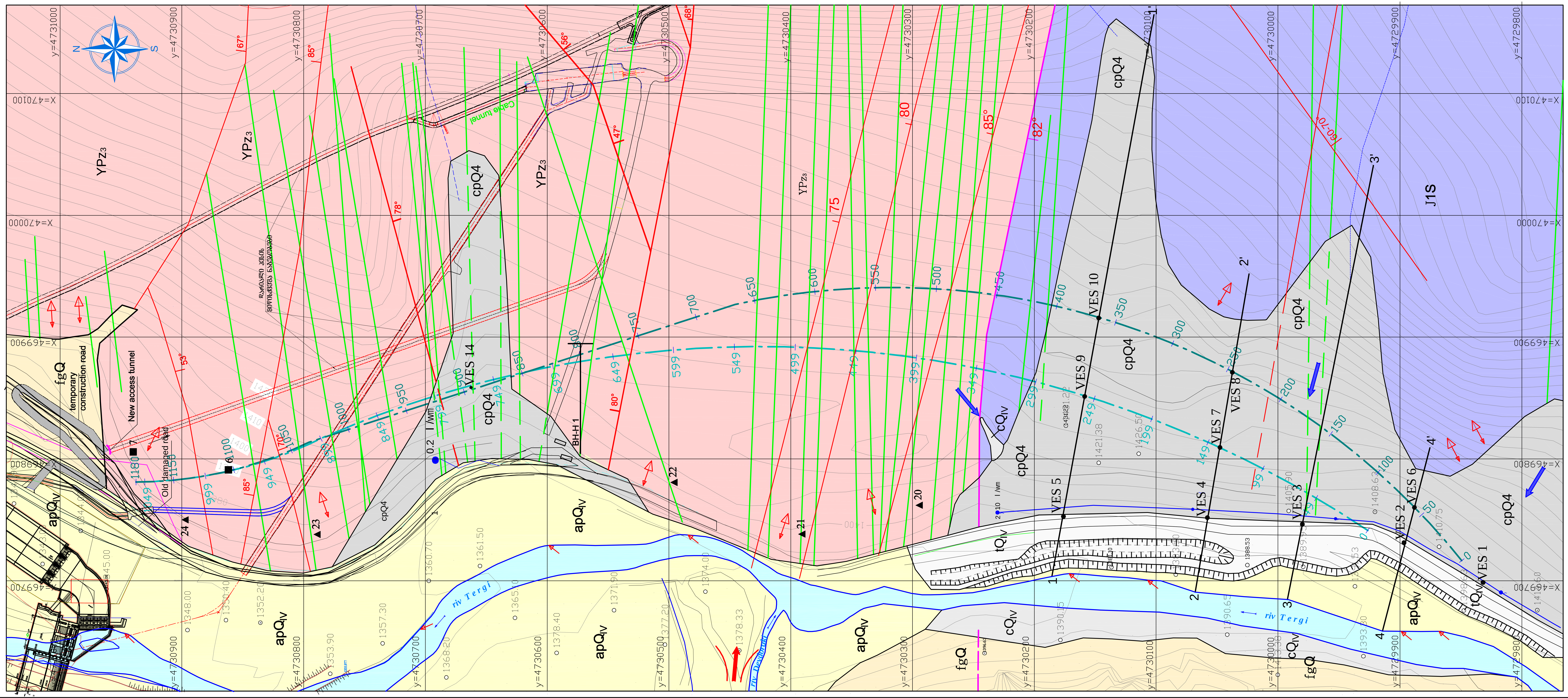
5.7 The rock mass rating has been assessed based on the documentation prepared during construction of the Dariali HPP tunnels. According to this assessment the following rock classes are expected for the both options of the tunnel: B (good), C (fair) and D (poor) class (see Table 4.3 and 4.4). Distribution of these classes, separately for Option I and Option II, represented in percentage is shown in the Tables 5.1 and 5.2 below:

***Table-5.1 Rock mass rating for tunnel option I***

| Rock class | % in massif |
|---|---|
| B class | 84.88 |
| C class | 7.37 |
| D class | 7.75 |

***Table-5.2 Rock mass rating for tunnel option II***

| Rock class | % in massif |
|---|---|
| B class | 84.42 |
| C class | 7.78 |
| D class | 7.80 |




## LEGEND:

| | |
|---|---|
| $tQ_{IV}$ | Quaternary system. Contemporaneous deposits. Fill ground. Angular and rounded gravel, cobbles, boulders |
| $cQ_{IV}$ | Quaternary system. Contemporaneous deposits. Colluvial. Angular and rounded gravel, cobbles with boulder content |
| $cpQ_{IV}$ | Quaternary system. Contemporaneous deposits. Colluvial-proluvial. Angular cobbles-37%, angular gravel-32% with boulders content-15% with some finer material-16%. |
| $apQ_{IV}$ | Quaternary system. Contemporaneous deposits. Alluvial. Boulders-40%, cobbles-35%, gravel-15%, with sand matrix-10%, dense. Some boulders are of 2-3 m diam. |
| fgQ | Quaternary system. Fluvioglacial deposits. Cobbles-40%, gravel-20%, boulders 15-20% with slightly cemented silty sand and intermediately plastic clay matrix 20-25% |
| $J_1S$ | Kistinki suite (upper part). Lower Jurassic. Sinemurian stage. Black slates. Lighter thin siltstones bands and gray arkosic sandstone, whitish quartzite and greenish tuff sandstone intercalations. |
| $yPZ_3$ | Upper Paleozoic. Fine and medium mylonitized sheeted granitoids |
| | Diabase dyke |
| | Geological border |
| | Protrusive borders of granitoids and sedimentary suites |
| | Tectonic fault |
| 85° | Large tectonic fractures, strike and dip angle |
| | Washout and wearing away (lateral erosion) of river banks |
| | Rock fall |
| | Mudflow |
| | Avalanche |
| 7 2 l /wm | Spring, its number (1) and water discharge (0.2) |
| | Frontal discharge of ground water |
| BH-H 1 | Horizontal borehole and its number |
| ვეზ-1 | Vertical Electrical Sounding test location and its number (01) |
| | Locations of discontinuity study of rocks |
| | Locations of sampling of rock outcrop |
| 1 1´ | Engineering-geological cross section line and its number |
| | Axis of designed motor road tunnel. 1st Option. |
| | Axis of designed motor road tunnel. 2nd Option. |

| | | |
|---|---|---|
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| | Engineering-geological Map | GC-1701-1 |
| | | Sheet 1 / 1 |
| | Scale: 1:2000 | Date: 2017 |


| | | | |
|---|---|---|---|
| Structural and tectonic description | | J1s - Lower Jurassic, Sinemurian, Kistinka Suite. Monocline of steep (75-85°) southward dip, with flexure bend of slopping morphology in the middle part. | yPz3 - Upper Paleozoic, Dariali granite massive, schistous, with subvertical schistosity, with tectonic fractures (75-85°) northward dip |
| Description of rocks | | Black slates with siltstone thin bands, with gray fine-grained arkosic sandstones (0.2-1.2m), whitish quartzite (1-4m), greenish tuff sandstones interlayers (5-20m), with diabase dikes | Mylonitized and schistous granitoids with diabase dikes |
| | | Slates with thin bends -47% with arkosic sandstones -20%, quartzite 9.9%, tuff sandstone -19%, Diabase-4.1% | Granitoid - 90.8%, Diabase - 9.2% |
| Physical-mechanical properties of rocks | | Slate: density $\rho$ = 2.80 gr/cm$^3$; compression strength, dry $\sigma_{uc\ dry}$ = 86.43 MPa; compression strength, saturated $\sigma_{uc\ sat}$ = 83.65 MPa; tuff sandstone: $\rho$ = 2.63 gr/cm$^3$; $\sigma_{uc\ dry}$ = 102.5 MPa; $\sigma_{uc\ sat}$ = 86.45 MPa; arkosic sandstones: $\rho$ = 2.75 gr/cm$^3$; $\sigma_{uc\ dry}$ = 122.89 MPa; $\sigma_{uc\ sat}$ = 119.22 MPa; quartzite: $\rho$ = 2.79 gr/cm$^3$; $\sigma_{uc\ dry}$ = 151.28 MPa; $\sigma_{uc\ sat}$ = 139.00 MPa; diabase: $\rho$ = 2.86 gr/cm$^3$; $\sigma_{uc\ dry}$ = 109.18 MPa; $\sigma_{uc\ sat}$ = 94.33 MPa | Granitoid: $\rho$ = 2.70 gr/cm$^3$; $\sigma_{uc\ dry}$ = 112.71 MPa; $\sigma_{uc\ sat}$ = 109.72 MPa; Diabase: $\rho$ = 2.86 gr/cm$^3$; $\sigma_{uc\ dry}$ = 109.18 MPa; $\sigma_{uc\ sat}$ = 94.33 MPa; |
| | | Average weighted: $\rho$ = 2.72 gr/cm$^3$; $\sigma_{uc\ dry}$ = 112.18 MPa; $\sigma_{uc\ sat}$ = 107.43 MPa | Average weighted: $\rho$ = 2.71 gr/cm$^3$; $\sigma_{uc\ dry}$ = 112.39 MPa; $\sigma_{uc\ sat}$ = 108.3 MPa |
| Discontinuity | | General direction of joints and tunnel axis is 70-80°. Joints dip is 50-80°. There are 3-5 joint sets. Average joint spacing is moderately to blocky (20-60cm.) and blocky to massive (60-200cm). In general the surface of joint is rough. | General direction of joints and tunnel axis is 70-72°. Joints dip is 50-80°. There are 3-5 joint sets. Average joint spacing is moderately to blocky (20-60cm.) and blocky to massive (60-200cm). In general the surface of joint is rough. |
| Type of water inflow | | Sporadical watered rocks. Fractured nonartesian water. The water is mainly hydrocarbonate calcium with salinity (0.1-0.6 gr/liter). Water inflow in tunnel is expected in form of downpour, in form of frequent downpour and water stream in large tectonic fractures. From 1 liter/min to 12 liter/min | Fractured nonartesian water. The water is hydrocarbonate with salinity (0.1-0.4 gr/liter). Water inflow in the tunnel is expected in form of downpour, in form of frequent downpour and water stream in large tectonic fractures. From 0.05 liter/min to 0.1 liter/min |

Q (Rock Quality Index), in order along the section:

- Q = 12.6 (Good, rock class B)
- Q = 11-18 - 75% (Good, rock class B); Q = 4-9 - 15% (Fair, rock class C); Q = 1-2 - 10% (Poor, rock class D)
- Q = 1-2 (Poor, rock class D)
- Q = 16-22 - 89% (Good, rock class B); Q = 6-10 - 6% (Fair, rock class C); Q = 1-2 - 5% (Poor, rock class D)
- Q = 1-2 (Poor, rock class D)
- Q = 14-34 (Good, rock class B); Q = 1-2 (Poor, rock class D)
- Q=16-32 B; Q = 1-2 (Poor, rock class D)
- Q = 19-26 (Good, rock class B)
- Q = 1-2 (Poor, rock class D)
- Q = 18-26 (Good, rock class B)
- Q = 16-40 (Good, rock class B); Q = 1-2 (Poor, rock class D)
- Q = 8-9 (Fair, rock class C)
- Q=16-18 (Good, rock class B); Q=1-2 (Poor, rock class D)
- Q=16-18 B; Q=1-2 (Poor, rock class D)
- Q=16-18 B; Q=1-2 (Poor, rock class D)
- Q=16-18 (Good, rock class B)

| Chainage | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Elevation | | 1429.85 | 1444.22 | 1444.51 | 1438.80 | 1440.80 | 1436.82 | 1427.24 | 1427.65 | 1414.39 | 1384.12 | |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Distance | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |

## LEGEND:

| | |
|---|---|
| cpQ$_{IV}$ | Quaternary system. Contemporaneous deposits. Colluvial-proluvial. Angular cobbles-37%, angular gravel-32% with boulders content-15% with some finer material-16%. |
| J$_1$S | Kistinki suite (upper part). Lower Jurassic. Sinemurian stage. Black slates. Lighter thin siltstones bands and gray arkosic sandstone, whitish quartzite and greenish tuff sandstone intercalations. |
| yPZ$_3$ | Upper Paleozoic. Fine and medium mylonitized sheeted granitoids |
| | Diabase dyke |
| | Geological border |
| | Protrusive borders of granitoids and sedimentary suites |
| | Regional tectonic fault (Saketseti fault) |
| | Large tectonic fractures, strike and dip angle |
| VES-7 | Vertical Electrical Sounding Test Location and its number |

| | | |
|---|---|---|
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| | Engineering-geological Sections | |
| | Dariali Road Tunnel 1 **Long Section** | GC-1701-2 **Sheet 1 / 1** |
| | Scale 1:1000 | Date: 2017 |


| | | |
|---|---|---|
| Structural and tectonic description | J1s - Lower Jurassic, Sinemurian, Kistinka Suite. Monocline of steep (75-85°) southward dip, with flexure bend of slopping morphology in the middle part. | γPz3 - Upper Paleozoic, Dariali granite massive, schistous, with subvertical schistosity, with tectonic fractures (75-85°) northward dip |
| Description of rocks | Black slates with siltstone thin bands, with gray fine-grained arkosic sandstones (0.2-1.2m), whitish quartzite (1-4m), greenish tuff sandstones interlayers (5-20m), with diabase dikes<br>Slates with thin bends -47%, arkosic sandstones -20%, quartzite 9.9%, tuff sandstone -19%, Diabase-4.1% | Mylonitized and schistous granitoids with diabase dikes<br>Granitoid - 90.8%, Diabase - 9.2% |
| Physical-mechanical properties of rocks | [illegible]: $\rho$ = 2.80; $\sigma_{uc}$ = 86.43; $\sigma_{uc\ sat}$ = 83.65; [illegible]: $\rho$ = 2.63; $\sigma_{uc}$ = 102.5; $\sigma_{uc\ sat}$ = 86.45; [illegible]: $\rho$ = 2.75; $\sigma_{uc}$ = 122.89; $\sigma_{uc\ sat}$ = 119.22; [illegible]: $\rho$ = 2.79; $\sigma_{uc}$ = 151.28; $\sigma_{uc\ sat}$ = 139.00; [illegible]: $\rho$ = 2.86; $\sigma_{uc}$ = 109.18; $\sigma_{uc\ sat}$ = 94.33<br>saSualo Sewonili: $\rho$ = 2.72 gr/sm$^3$; $\sigma_{uc\ dry}$ = 112.18 mpa; $\sigma_{uc\ sat}$ = 107.43 mpa | granitoidi: $\rho$ = 2.70 gr/sm$^3$; $\sigma_{uc\ dry}$ = 112.71 mpa; $\sigma_{uc\ sat}$ = 109.72 mpa;<br>diabazi: $\rho$ = 2.86 gr/sm$^3$; $\sigma_{uc\ dry}$ = 109.18 mpa; $\sigma_{uc\ sat}$ = 94.33 mpa;<br>saSualo Sewonili: $\rho$ = 2.71 gr/sm$^3$; $\sigma_{uc\ dry}$ = 112.39 mpa; $\sigma_{uc\ sat}$ = 108.3 mpa |
| Discontinuity | ZiriTadi napralebis mimarTebasa da gvirabis RerZs Soris kuTxe Seadgens 70-80 °. napralebis daxriloba Seadgens 50-80 °. fiqsirdeba napralTa 3-5 sistema. napralTa Soris manZili saSualodan blokuramde (20-60 sm) da blokuridan masiuramde (60-200 sm), napralTa zedapirebi ZiriTadad xorkliania. | ZiriTadi napralebis mimarTebasa da gvirabis RerZs Soris kuTxe Seadgens 70-72 °. napralebis daxriloba da Seadgens 50-80 °. fiqsirdeba napralTa 3-5 sistema. napralTa Soris manZili saSualodan blokuramde (20-60 sm) da blokuridan masiuramde (60-200 sm), napralTa zedapirebi ZiriTadad xorkliania. |
| Type of water inflow | sporadulad gawylianebuli qanebi. napralovani cirkulaciis uwnevo wylebi. wylebi hidrokarbonatul-kalciumiania, mineralizaciiT (0.1-0.6gr/l). gvirabSi wyalmodena mosalodnelia wveTvis saxiT, msxvil teqtonikur napralebSi xSiri wveTvisa da nakadis saxiT.<br>1 - 12 l/wT | napralovani cirkulaciis uwnevo wylebi. wylebi hidrokarbonatul-kalciumiania, mineralizaciiT (0.1-0.4 gr/l). gvirabSi wyalmodena mosalodnelia wveTvis saxiT, msxvil teqtonikur napralebSi xSiri wveTvisa da nakadis saxiT<br>0.05 - 0.1 l/wT |
| Q (Rock Quality Index) | Q = 11-18 - 75% (kargi, B klasis qanebi); Q = 4-9 - 15% (saSualo, C klasis qanebi); Q = 1-2 - 10% (cudi, D klasis qanebi); Q=1-2 - 10% (cudi, D klasis qanebi); Q = 16-22 - 89% (kargi, B klasis qanebi); Q = 6-10 - 6% (saSualo, C klasis qanebi); Q = 1-2 - 5% (cudi, D klasis qanebi) | Q=14-34 (kargi, B klasis qanebi); Q=1-2 10% (cudi, D klasis qanebi); Q = 16-32 kargi, B klasis qanebi; Q=1-2 10% (cudi, D klasis qanebi); Q = 19-26 kargi, B klasis qanebi; Q=1-2 10% (cudi, D klasis qanebi); Q = 18-26 (kargi, B klasis qanebi); Q=1-2 - 10% (cudi, D klasis qanebi); Q = 16-40 (kargi, B klasis qanebi); Q=1-2 - 10% (cudi, D klasis qanebi); Q = 8-9 (saSualo, C klasis qanebi); Q=16-18 (kargi, B klasis qanebi); Q=1-2 cudi, D klasis qanebi; Q=16-18 (kargi, B klasis qanebi); Q=1-2 cudi, D klasis qanebi; Q=16-18 B; Q=1-2 cudi, D klasis qanebi; Q=16-18 (kargi, B klasis qanebi); Q=1-2 cudi, D klasis qanebi |

| Elevation | | 1412.90 | 1428.24 | 1454.04 | 1468.23 | 1477.49 | 1469.73 | 1465.80 | 1448.58 | 1424.45 | 1419.29 | 1418.71 | 1390.17 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Distance | -49 | | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| Chainage | -49 | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |

# LEGEND:

- cpQIV — Quaternary system. Contemporaneous deposits. Colluvial-proluvial. Angular cobbles-37%, angular gravel-32% with boulders content-15% with some finer material-16%.
- J1S — Kistinki suite (upper part). Lower Jurassic. Sinemurian stage. Black slates. Lighter thin siltstones bands and gray arkosic sandstone, whitish quartzite and greenish tuff sandstone intercalations.
- yPZ3 — Upper Paleozoic. Fine and medium mylonitized sheeted granitoids
- Diabase dyke
- Geological border
- Protrusive borders of granitoids and sedimentary suites
- Regional tectonic fault (Saketseti fault)
- Large tectonic fractures, strike and dip angle
- VES-6 — Vertical Electrical Sounding Test Location and its number

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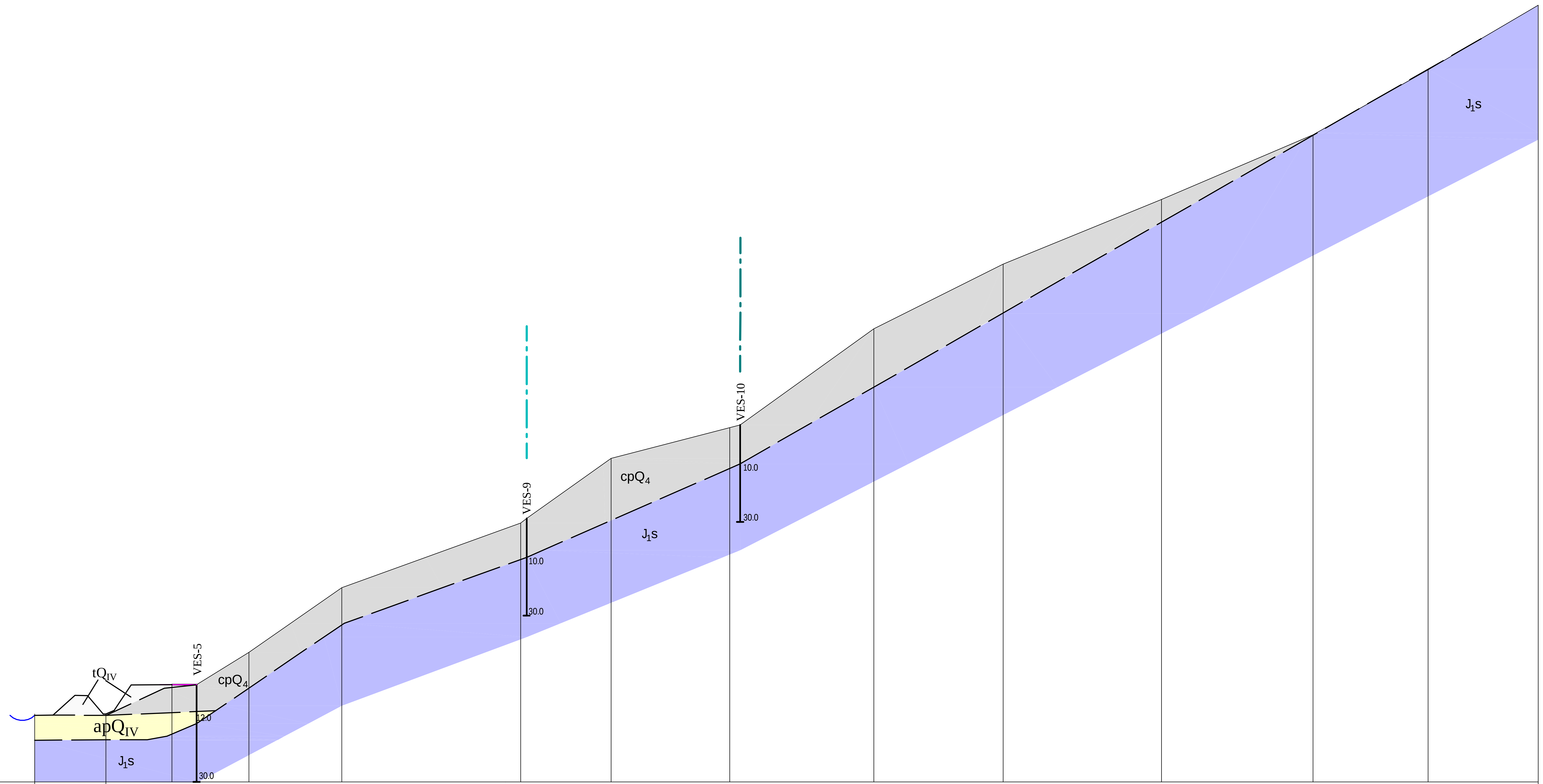
**Provision of Geotechnical Investigation for New Road Tunnel and Overpass in Dariali Valley, Georgia**

Engineering-geological Sections

Dariali Road Tunnel 2
Long Section

GC-1701-3
**Sheet 1 / 1**
Scale 1:1000
Date: 2017




| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Elevations | 1380 | 1381 | 1390 | 1390 | 1400 | 1420 | 1440 1441.4 | 1460 | 1470.3 | 1500 | 1520 | 1540 | 1560 | 1580 | 1600 |
| Distance | 22.1 | 20.4 | 7.6 | 16.2 | 28.7 | 55.3 | 27.9 | 36.7 | 44.5 | 40.0 | 48.9 | 46.8 | 35.6 | 34.0 | |

## LEGEND:

| | |
|---|---|
| $tQ_{IV}$ | Quaternary system. Contemporaneous deposits. Fill ground. Angular and rounded gravel, cobbles, boulders |
| $cQ_{IV}$ | Quaternary system. Contemporaneous deposits. Colluvial. Angular and rounded gravel, cobbles with boulder content |
| $cpQ_{IV}$ | Quaternary system. Contemporaneous deposits. Colluvial-proluvial. Angular cobbles-37%, angular gravel-32% with boulders content-15% with some finer material-16%. |
| $apQ_{IV}$ | Quaternary system. Contemporaneous deposits. Alluvial. Boulders-40%, cobbles-35%, gravel-15%, with sand matrix-10%, dense. Some boulders are of 2-3 m diam. |
| $J_1S$ | Kistinki suite (upper part). Lower Jurassic. Sinemurian stage. Black slates. Lighter thin siltstones bands and gray arkosic sandstone, whitish quartzite and greenish tuff sandstone intercalations. |
| | Geological border |
| VES-9 30.0 | Vertical Electrical Sounding test location and its number (01) |
| | Axis of designed motor road tunnel. Option I. |
| | Axis of designed motor road tunnel. Option II. |

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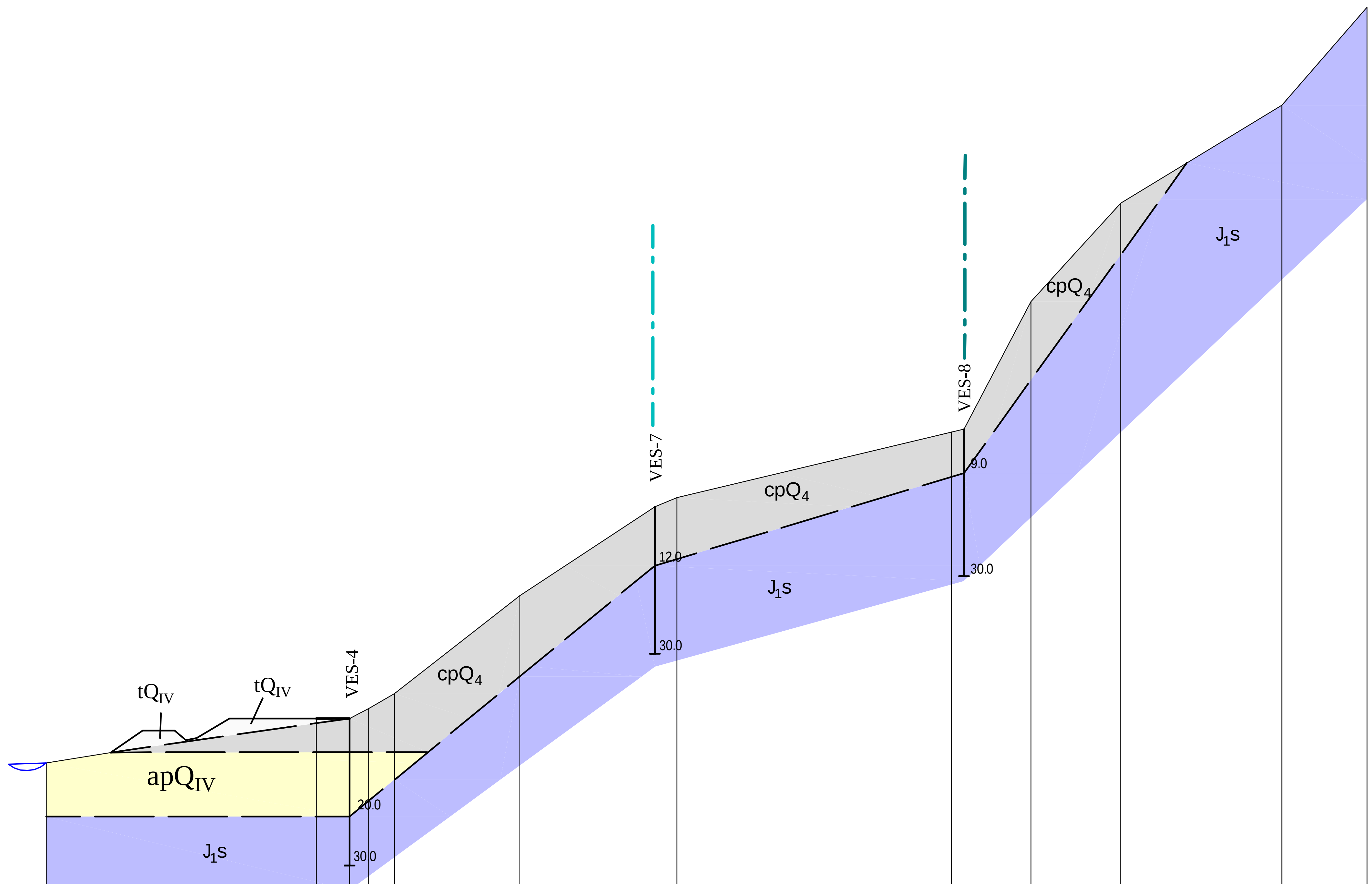
Provision of Geotechnical Investigation for New Road Tunnel and Overpass in Dariali Valley, Georgia

Engineering-geological Sections

| | |
|---|---|
| Gross Section 1-1' | GC-1701-4.1 |
| | Sheet 1 / 4 |
| Scale 1:1000 | Date: 2017 |




| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Elevations | 1386 | 1395 | 1395 | 1397 | 1400 | 1420 | 1438.14 | 1440 | | 1480 | 1500 | 1520 | 1540 |
| Distance | 51.2 | 6.8 | 3.9 | 5.2 | 25.6 | 32.0 | 56.0 | | 16.1 | 18.3 | 32.9 | 17.3 | |

## LEGEND:

| Symbol | Description |
|---|---|
| $tQ_{IV}$ | Quaternary system. Contemporaneous deposits. Fill ground. Angular and rounded gravel, cobbles, boulders |
| $cQ_{IV}$ | Quaternary system. Contemporaneous deposits. Colluvial. Angular and rounded gravel, cobbles with boulder content |
| $cpQ_{IV}$ | Quaternary system. Contemporaneous deposits. Colluvial-proluvial. Angular cobbles-37%, angular gravel-32% with boulders content-15% with some finer material-16%. |
| $apQ_{IV}$ | Quaternary system. Contemporaneous deposits. Alluvial. Boulders-40%, cobbles-35%, gravel-15%, with sand matrix-10%, dense. Some boulders are of 2-3 m diam. |
| $J_1S$ | Kistinki suite (upper part). Lower Jurassic. Sinemurian stage. Black slates. Lighter thin siltstones bands and gray arkosic sandstone, whitish quartzite and greenish tuff sandstone intercalations. |
| | Geological border |
| VES-9 30.0 | Vertical Electrical Sounding test location and its number (01) |
| | Axis of designed motor road tunnel. Option I. |
| | Axis of designed motor road tunnel. Option II. |

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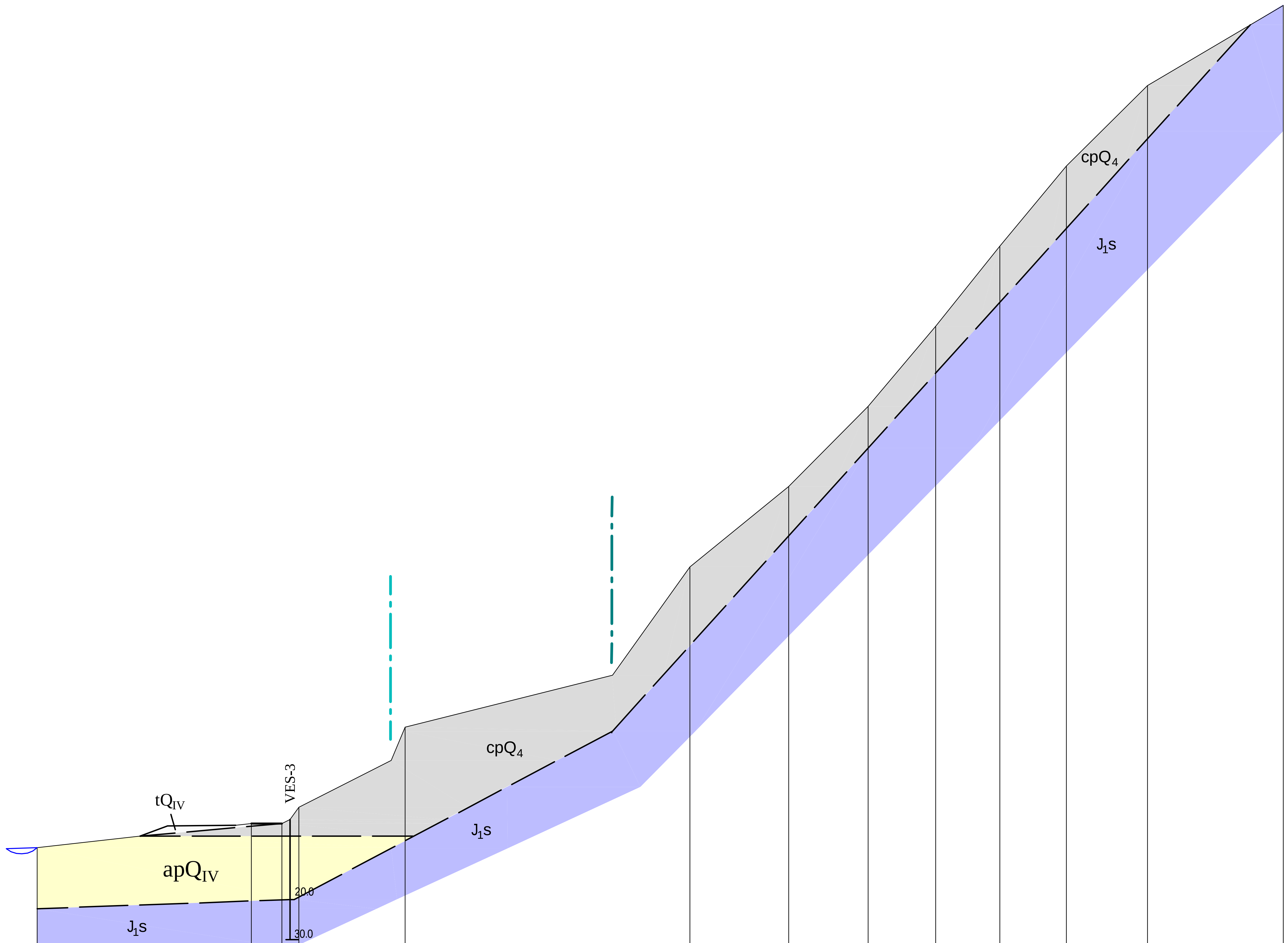
**Provision of Geotechnical Investigation for New Road Tunnel and Overpass in Dariali Valley, Georgia**

Engineering-geological Sections

| | |
|---|---|
| **Gross Section 2-2'** | GC-1701-4.2 |
| | **Sheet 2 / 4** |
| Scale 1:1000 | Date: 2017 |

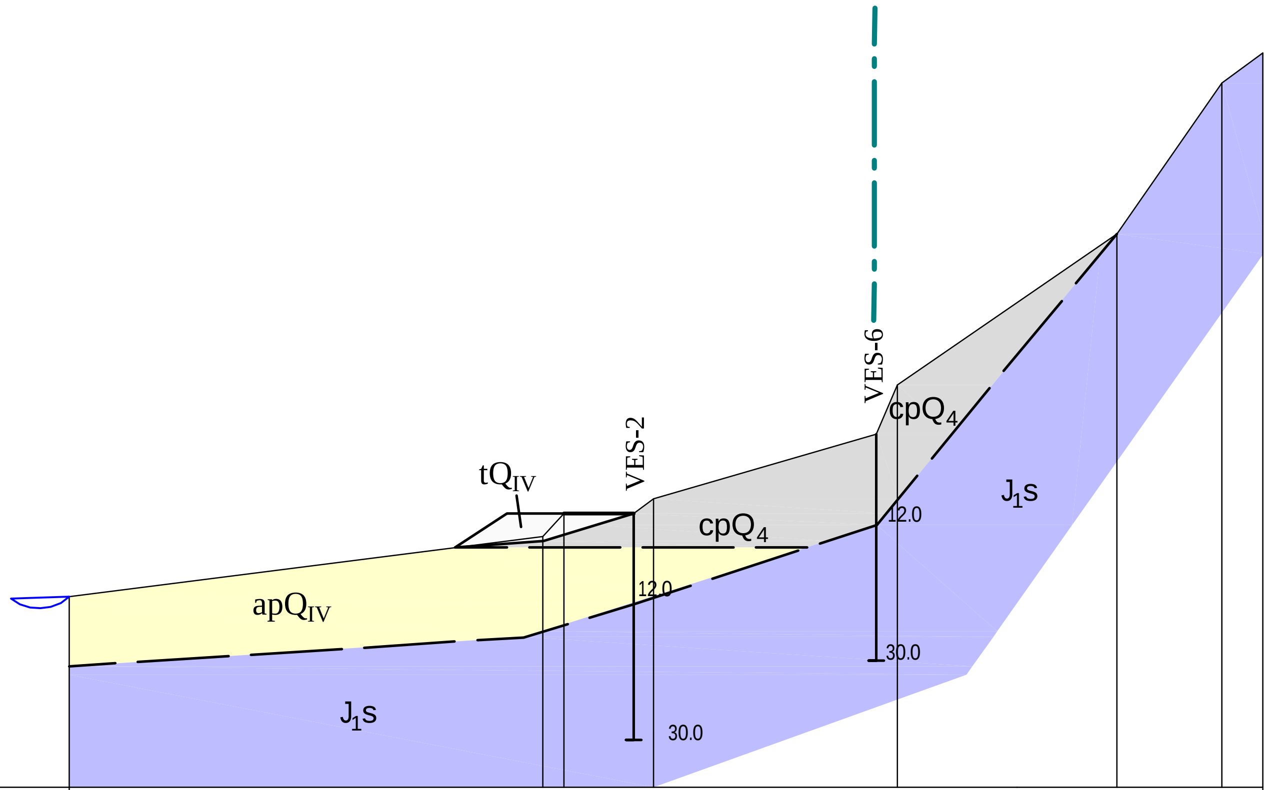



| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Elevations | 1390 | 1396 | 1396 1397 1400 | 1411.7 1420 | | 1460 | 1480 | 1500 | 1520 | 1540 | 1560 | 1580 | 1600 | |
| Distance | 50.8 | 7.6 | 2.1 2.2 | 26.5 | 41.5 | 29.5 | 24.7 | 19.8 | 16.8 | 16.0 | 16.6 | 20.3 | 33.8 | |

## LEGEND:

| | |
|---|---|
| $tQ_{IV}$ | Quaternary system. Contemporaneous deposits. Fill ground. Angular and rounded gravel, cobbles, boulders |
| $cQ_{IV}$ | Quaternary system. Contemporaneous deposits. Colluvial. Angular and rounded gravel, cobbles with boulder content |
| $cpQ_{IV}$ | Quaternary system. Contemporaneous deposits. Colluvial-proluvial. Angular cobbles-37%, angular gravel-32% with boulders content-15% with some finer material-16%. |
| $apQ_{IV}$ | Quaternary system. Contemporaneous deposits. Alluvial. Boulders-40%, cobbles-35%, gravel-15%, with sand matrix-10%, dense. Some boulders are of 2-3 m diam. |
| $J_1S$ | Kistinki suite (upper part). Lower Jurassic. Sinemurian stage. Black slates. Lighter thin siltstones bands and gray arkosic sandstone, whitish quartzite and greenish tuff sandstone intercalations. |
| | Geological border |
| VES-9 30.0 | Vertical Electrical Sounding test location and its number (01) |
| | Axis of designed motor road tunnel. Option I. |
| | Axis of designed motor road tunnel. Option II. |

| | | |
|---|---|---|
| **GEOENGINEERING LTD.** Civil Engineering - Survey, Design, Construction, Consulting | Provision of Geotechnical Investigation for New Road Tunnel and Overpass in Dariali Valley, Georgia | |
| GEOENGINEERING | Engineering-geological Sections | |
| | Gross Section 3-3' | GC-1701-4.3 |
| | | **Sheet 3 / 4** |
| | Scale 1:1000 | Date: 2017 |




| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Elevations | 1392 | 1400 1403 | | 1403 1405 | | 1413.5 1420 | 1440 | 1460 1464 |
| Distance | 60.7 | 2.8 | 9.2 | 2.6 | 32.3 | 29.0 | 13.9 | 5.40 |

## LEGEND:

| | |
|---|---|
| $tQ_{IV}$ | Quaternary system. Contemporaneous deposits. Fill ground. Angular and rounded gravel, cobbles, boulders |
| $cQ_{IV}$ | Quaternary system. Contemporaneous deposits. Colluvial. Angular and rounded gravel, cobbles with boulder content |
| $cpQ_{IV}$ | Quaternary system. Contemporaneous deposits. Colluvial-proluvial. Angular cobbles-37%, angular gravel-32% with boulders content-15% with some finer material-16%. |
| $apQ_{IV}$ | Quaternary system. Contemporaneous deposits. Alluvial. Boulders-40%, cobbles-35%, gravel-15%, with sand matrix-10%, dense. Some boulders are of 2-3 m diam. |
| $J_1S$ | Kistinki suite (upper part). Lower Jurassic. Sinemurian stage. Black slates. Lighter thin siltstones bands and gray arkosic sandstone, whitish quartzite and greenish tuff sandstone intercalations. |
| | Geological border |
| VES-9 30.0 | Vertical Electrical Sounding test location and its number (01) |
| | Axis of designed motor road tunnel. Option I. |
| | Axis of designed motor road tunnel. Option II. |

| | | |
|---|---|---|
| **GEOENGINEERING LTD.** Civil Engineering - Survey, Design, Construction, Consulting | Provision of Geotechnical Investigation for New Road Tunnel and Overpass in Dariali Valley, Georgia | |
| | Engineering-geological Sections | |
| | Gross Section 4-4' | GC-1701-4.4 |
| | | **Sheet 4 / 4** |
| | Scale 1:1000 | Date: 2017 |

ხელშეკრულება/**Contract No. GC-1701**

<u>პროექტის დასახელება:</u> საქართველოში, დარიალის ხეობაში გზის ახალი გვირაბის და ესტაკადის გეოტექნიკური გამოკვლევა

**<u>Ptoject Name:</u>** Provision of Geotechnical Investigation for New Road Tunnel and Overpass in Dariali Valley, Georgia

## ᲕᲔᲠᲢᲘᲙᲐᲚᲣᲠᲘ ᲔᲚᲔᲥᲢᲠᲝᲖᲝᲜᲓᲘᲠᲔᲑᲘᲡ ᲨᲔᲓᲔᲒᲔᲑᲘ, ᲯᲐᲛᲣᲠᲘ ᲪᲮᲠᲘᲚᲘ

## Results of Vertical Electric Sounding, Total Table

| ᲕᲔᲖᲘᲡ № VES № | ᲥᲐᲜᲔᲑᲘᲡ ᲡᲘᲦᲠᲛᲣᲚᲘ ᲒᲐᲜᲚᲐᲒᲔᲑᲐ, Მ Layer depth, m | ᲔᲚᲔᲥᲢᲠᲝ-ᲬᲘᲜᲐᲦᲝᲑᲐ ρ ᲝᲛ.Მ Electric Resistivity, ρ ohm. m | ᲕᲔᲖ-ის კოორდინატები VES Coordinates | |
|---|---|---|---|---|
| | | | X | Y |
| VES-1 | 0,0-12,0 | 500 | 469698 | 4729832 |
| | 12,0-30,0 | 200 | | |
| VES-2 | 0,0-12,0 | 450 | 469731 | 4729896 |
| | 12,0-30,0 | 190 | | |
| VES-3 | 0,0-20,0 | 500 | 469747 | 4729980 |
| | 20,0-30,0 | 150 | | |
| VES-4 | 0,0-20,0 | 500 | 469751 | 4730058 |
| | 20,0-30,0 | 220 | | |
| VES-5 | 0,0-12,0 | 500 | 469753 | 4730176 |
| | 12,0-30,0 | 200 | | |
| VES-6 | 0,0-12,0 | 800 | 469760 | 4729888 |
| | 12,0-30,0 | 250 | | |
| VES-7 | 0,0-12,0 | 950 | 469810 | 4730048 |
| | 12,0-30,0 | 250 | | |
| VES-8 | 0,0-9,0 | 960 | 469871 | 4730038 |
| | 9,0-30,0 | 210 | | |
| VES-9 | 0,0-10,0 | 980 | 469852 | 4730158 |
| | 10,0-30,0 | 220 | | |
| VES-10 | 0,0-10,0 | 970 | 469916 | 4730147 |
| | 10,0-30,0 | 190 | | |

**Contract No. GC-1701**

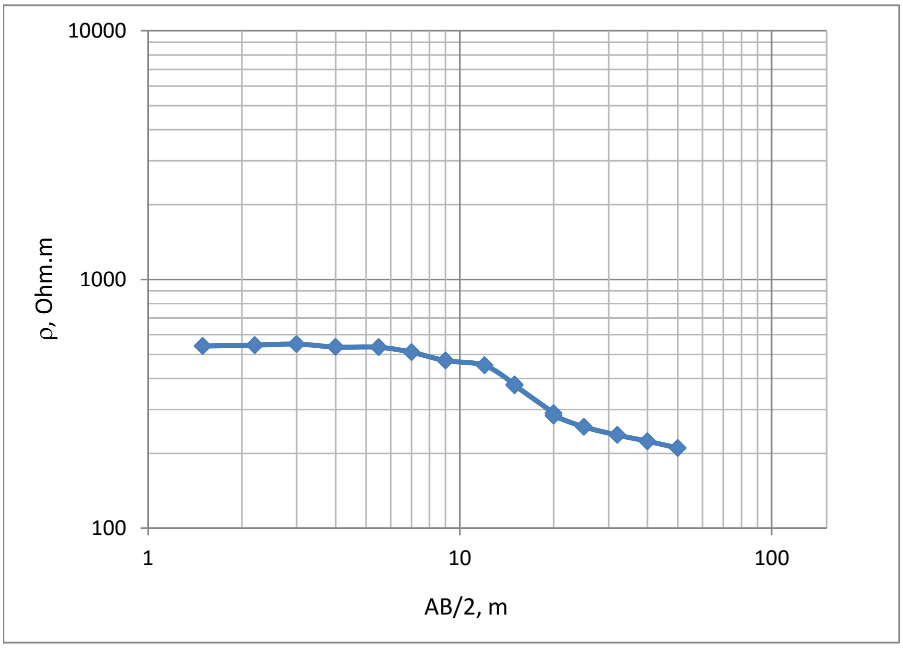
**Ptoject Name:** Provision of Geotechnical Investigation for New Road Tunnel and Overpass in Dariali Valley, Georgia

**Location:**

| X | Y |
|---|---|
| 469698 | 4729832 |

## VES No. 1

| № | AB/2 | MN | K' | K | ΔV | I | ρ |
|---|---|---|---|---|---|---|---|
| 1 | 1.5 | 1 | | 0.628 | 860 | 1 | 540.08 |
| 2 | 2.2 | 1 | | 1.44 | 870 | 2.3 | 544.70 |
| 3 | 3 | 1 | | 2.75 | 120 | 0.6 | 550.00 |
| 1 | 4 | 1 | | 4.95 | 200 | 1.85 | 535.14 |
| 2 | 5.5 | 1 | | 9.42 | 85 | 1.5 | 533.80 |
| 3 | 7 | 1 | | 15.3 | 30 | 0.9 | 510.00 |
| 1 | 9 | 1 | | 25.36 | 80 | 4.3 | 471.81 |
| 2 | 12 | 1 | | 45.14 | 39 | 3.9 | 451.40 |
| 3 | 15 | 1 | | 70.5 | 22 | 4.1 | 378.29 |
| 3 | 15 | 10 | | 6.28 | 245 | 4.1 | 375.27 |
| 1 | 20 | 1 | | 125.52 | 12 | 5.2 | 289.66 |
| 1 | 20 | 10 | | 11.78 | 125 | 5.2 | 283.17 |
| 2 | 25 | 10 | 196.17 | 18.84 | 80 | 5.9 | 255.46 |
| 3 | 32 | 10 | 321.45 | 31.37 | 37 | 4.9 | 236.88 |
| 1 | 40 | 10 | | 49.45 | 19 | 4.2 | 223.70 |
| 2 | 50 | 10 | | 77.72 | 10 | 3.7 | 210.05 |




Results

| VES No. | Layer depth, m | Electric Resistivity, δ Ohm, m |
|---|---|---|
| 1 | 0,0-12,0<br>12,0-30,0 | 500<br>200 |

**Contract No. GC-1701**

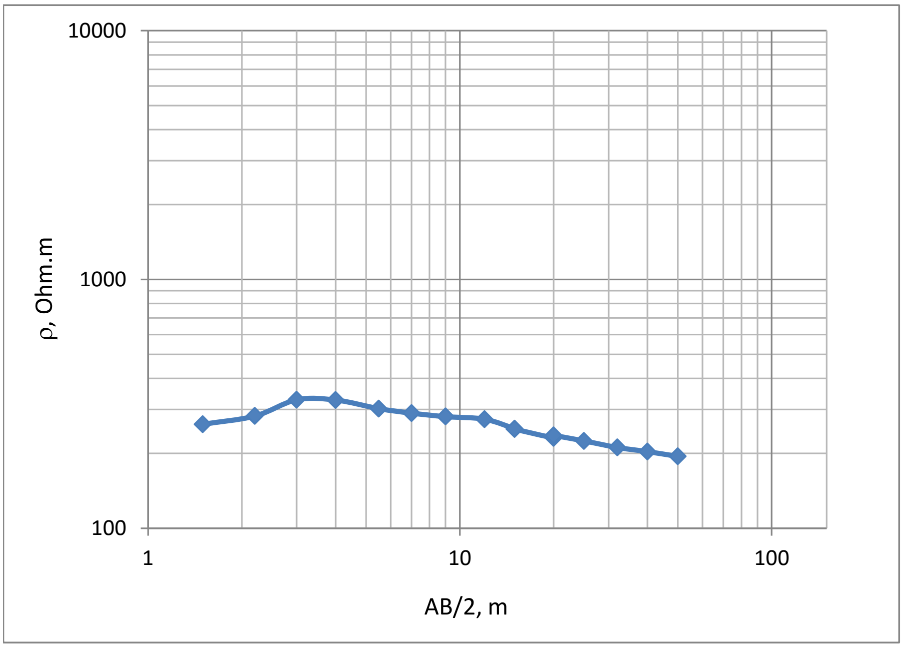
**Ptoject Name:** Provision of Geotechnical Investigation for New Road Tunnel and Overpass in Dariali Valley, Georgia

**Location:**

| X | Y |
|---|---|
| 469731 | 4729896 |

## VES No. 2

| № | AB/2 | MN | K' | K | ΔV | I | ρ |
|---|---|---|---|---|---|---|---|
| 1 | 1.5 | 1 | | 0.628 | 500 | 1.2 | 261.67 |
| 2 | 2.2 | 1 | | 1.44 | 980 | 5 | 282.24 |
| 3 | 3 | 1 | | 2.75 | 800 | 6.7 | 328.36 |
| 1 | 4 | 1 | | 4.95 | 430 | 6.5 | 327.46 |
| 2 | 5.5 | 1 | | 9.42 | 260 | 8.1 | 302.37 |
| 3 | 7 | 1 | | 15.3 | 127 | 6.7 | 290.01 |
| 1 | 9 | 1 | | 25.36 | 62 | 5.6 | 280.77 |
| 2 | 12 | 1 | | 45.14 | 48 | 7.9 | 274.27 |
| 3 | 15 | 1 | | 70.5 | 21 | 5.9 | 250.93 |
| 3 | 15 | 10 | | 6.28 | 235 | 5.9 | 250.14 |
| 1 | 20 | 1 | | 125.52 | 9 | 4.9 | 230.55 |
| 1 | 20 | 10 | | 11.78 | 98 | 4.9 | 235.60 |
| 2 | 25 | 10 | 196.17 | 18.84 | 75 | 6.3 | 224.29 |
| 3 | 32 | 10 | 321.45 | 31.37 | 37 | 5.5 | 211.03 |
| 1 | 40 | 10 | | 49.45 | 11.5 | 2.8 | 203.10 |
| 2 | 50 | 10 | | 77.72 | 12.5 | 5 | 194.30 |




Results

| VES No. | Layer depth, m | Electric Resistivity, δ Ohm, m |
|---|---|---|
| 2 | 0,0-12,0<br>12,0-30,0 | 450<br>190 |

**Contract No. GC-1701**

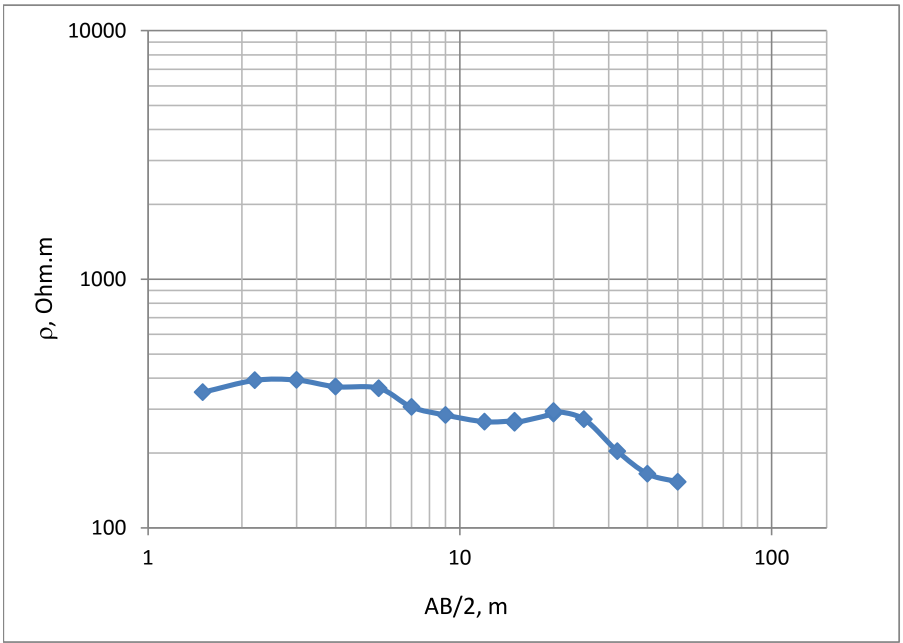
**Ptoject Name:** Provision of Geotechnical Investigation for New Road Tunnel and Overpass in Dariali Valley, Georgia

**Location:**

| X | Y |
|---|---|
| 469747 | 4729980 |

## VES No. 3

| № | AB/2 | MN | K' | K | ΔV | I | ρ |
|---|---|---|---|---|---|---|---|
| 1 | 1.5 | 1 | | 0.628 | 950 | 1.7 | 350.94 |
| 2 | 2.2 | 1 | | 1.44 | 680 | 2.5 | 391.68 |
| 3 | 3 | 1 | | 2.75 | 700 | 4.9 | 392.86 |
| 1 | 4 | 1 | | 4.95 | 500 | 6.7 | 369.40 |
| 2 | 5.5 | 1 | | 9.42 | 58 | 1.5 | 364.24 |
| 3 | 7 | 1 | | 15.3 | 110 | 5.5 | 306.00 |
| 1 | 9 | 1 | | 25.36 | 84 | 7.5 | 284.03 |
| 2 | 12 | 1 | | 45.14 | 42 | 7.1 | 267.03 |
| 3 | 15 | 1 | | 70.5 | 14.5 | 3.8 | 269.01 |
| 3 | 15 | 10 | | 6.28 | 160 | 3.8 | 264.42 |
| 1 | 20 | 1 | | 125.52 | 11 | 4.8 | 287.65 |
| 1 | 20 | 10 | | 11.78 | 120 | 4.8 | 294.50 |
| 2 | 25 | 10 | 196.17 | 18.84 | 90 | 6.2 | 273.48 |
| 3 | 32 | 10 | 321.45 | 31.37 | 57 | 8.8 | 203.19 |
| 1 | 40 | 10 | | 49.45 | 11 | 3.3 | 164.83 |
| 2 | 50 | 10 | | 77.72 | 6.3 | 3.2 | 153.01 |




Results

| VES No. | Layer depth, m | Electric Resistivity, δ Ohm, m |
|---|---|---|
| 3 | 0,0-20,0<br>20,0-30,0 | 500<br>150 |

**Contract No. GC-1701**

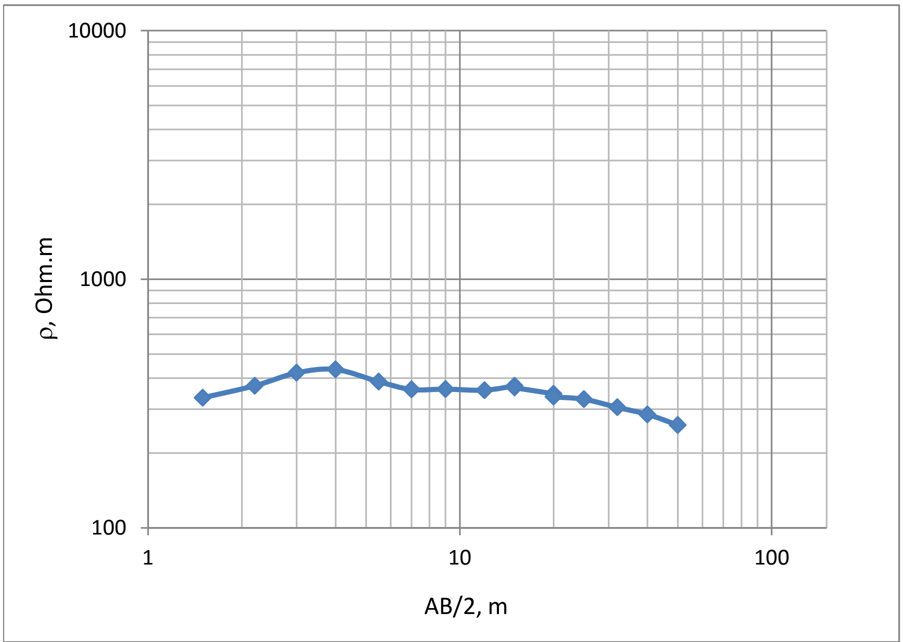
**Ptoject Name:** Provision of Geotechnical Investigation for New Road Tunnel and Overpass in Dariali Valley, Georgia

**Location:**

| X | Y |
|---|---|
| 469751 | 4730058 |

## VES No. 4

| № | AB/2 | MN | K' | K | ΔV | I | ρ |
|---|---|---|---|---|---|---|---|
| 1 | 1.5 | 1 | | 0.628 | 850 | 1.6 | 333.63 |
| 2 | 2.2 | 1 | | 1.44 | 880 | 3.4 | 372.71 |
| 3 | 3 | 1 | | 2.75 | 550 | 3.6 | 420.14 |
| 1 | 4 | 1 | | 4.95 | 210 | 2.4 | 433.13 |
| 2 | 5.5 | 1 | | 9.42 | 152 | 3.7 | 386.98 |
| 3 | 7 | 1 | | 15.3 | 80 | 3.4 | 360.00 |
| 1 | 9 | 1 | | 25.36 | 47 | 3.3 | 361.19 |
| 2 | 12 | 1 | | 45.14 | 42 | 5.3 | 357.71 |
| 3 | 15 | 1 | | 70.5 | 19 | 3.6 | 372.08 |
| 3 | 15 | 10 | | 6.28 | 210 | 3.6 | 366.33 |
| 1 | 20 | 1 | | 125.52 | 7.7 | 2.8 | 345.18 |
| 1 | 20 | 10 | | 11.78 | 80 | 2.8 | 336.57 |
| 2 | 25 | 10 | 196.17 | 18.84 | 62 | 3.55 | 329.04 |
| 3 | 32 | 10 | 321.45 | 31.37 | 35 | 3.6 | 304.99 |
| 1 | 40 | 10 | | 49.45 | 26 | 4.5 | 285.71 |
| 2 | 50 | 10 | | 77.72 | 10.3 | 3.09 | 259.07 |




Results

| VES No. | Layer depth, m | Electric Resistivity, δ Ohm, m |
|---|---|---|
| 4 | 0,0-20,0<br>20,0-30,0 | 500<br>220 |

**Contract No. GC-1701**

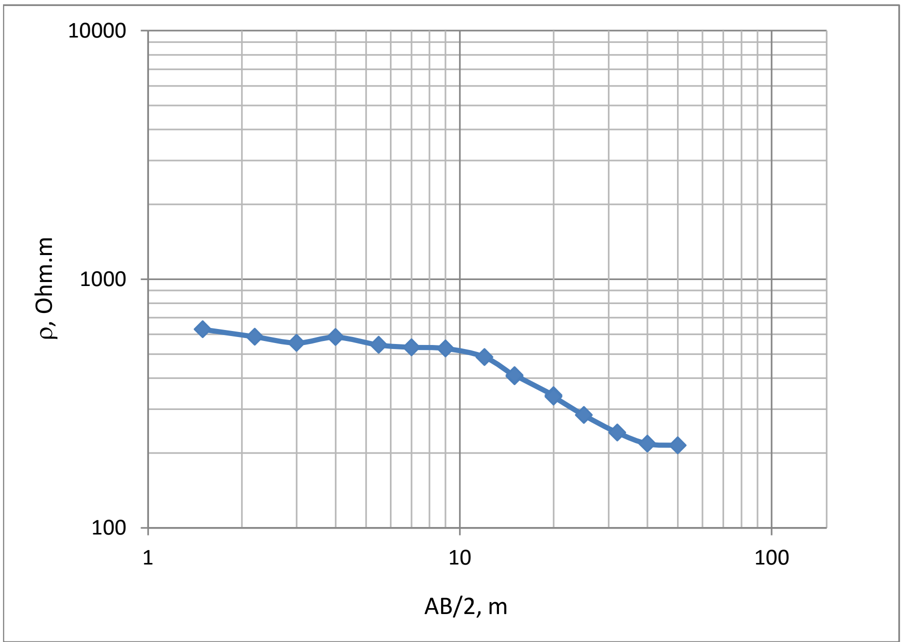
**Ptoject Name:** Provision of Geotechnical Investigation for New Road Tunnel and Overpass in Dariali Valley, Georgia

**Location:**

| X | Y |
|---|---|
| 469753 | 4730176 |

**VES No. 5**

| № | AB/2 | MN | K' | K | ΔV | I | ρ |
|---|---|---|---|---|---|---|---|
| 1 | 1.5 | 1 | | 0.628 | 300 | 0.3 | 628.00 |
| 2 | 2.2 | 1 | | 1.44 | 220 | 0.54 | 586.67 |
| 3 | 3 | 1 | | 2.75 | 135 | 0.67 | 554.10 |
| 1 | 4 | 1 | | 4.95 | 59 | 0.5 | 584.10 |
| 2 | 5.5 | 1 | | 9.42 | 45 | 0.78 | 543.46 |
| 3 | 7 | 1 | | 15.3 | 24 | 0.69 | 532.17 |
| 1 | 9 | 1 | | 25.36 | 8.3 | 0.4 | 526.22 |
| 2 | 12 | 1 | | 45.14 | 28 | 2.6 | 486.12 |
| 3 | 15 | 1 | | 70.5 | 15 | 2.6 | 406.73 |
| 3 | 15 | 10 | | 6.28 | 170 | 2.6 | 410.62 |
| 1 | 20 | 1 | | 125.52 | 1.9 | 0.7 | 340.70 |
| 1 | 20 | 10 | | 11.78 | 20 | 0.7 | 336.57 |
| 2 | 25 | 10 | 196.17 | 18.84 | 12.8 | 0.85 | 283.71 |
| 3 | 32 | 10 | 321.45 | 31.37 | 5 | 0.65 | 241.31 |
| 1 | 40 | 10 | | 49.45 | 11 | 2.5 | 217.58 |
| 2 | 50 | 10 | | 77.72 | 6.9 | 2.5 | 214.51 |




Results

| VES No. | Layer depth, m | Electric Resistivity, δ Ohm, m |
|---|---|---|
| 5 | 0,0-12,0<br>12,0-30,0 | 500<br>200 |

**Contract No. GC-1701**

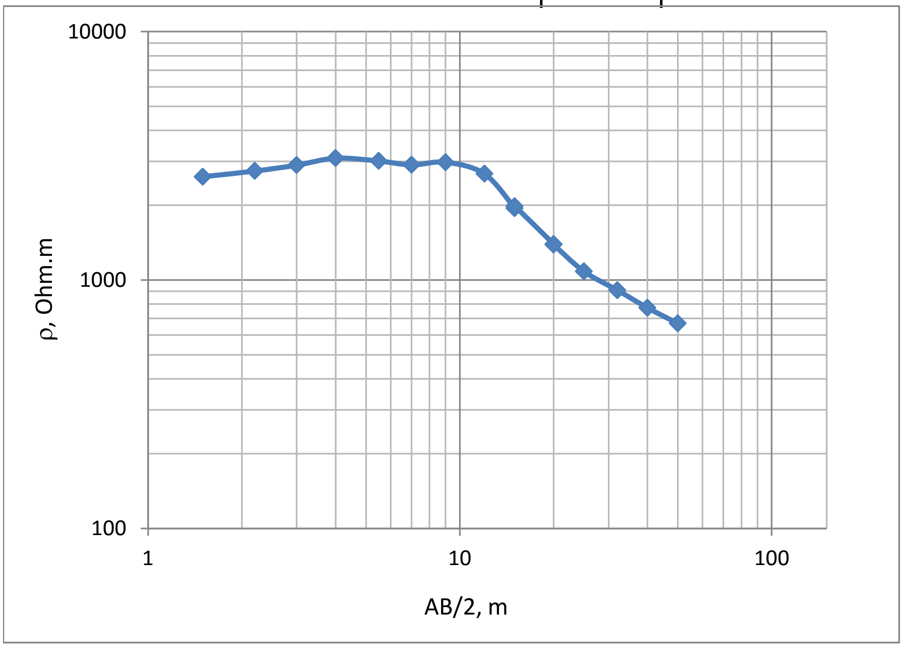
**Ptoject Name:** Provision of Geotechnical Investigation for New Road Tunnel and Overpass in Dariali Valley, Georgia

**Location:**

| X | Y |
|---|---|
| 469760 | 4729888 |

## VES No. 6

| № | AB/2 | MN | K' | K | ΔV | I | ρ |
|---|---|---|---|---|---|---|---|
| 1 | 1.5 | 1 | | 0.628 | 415 | 0.1 | 2606.20 |
| 2 | 2.2 | 1 | | 1.44 | 286 | 0.15 | 2745.60 |
| 3 | 3 | 1 | | 2.75 | 232 | 0.22 | 2900.00 |
| 1 | 4 | 1 | | 4.95 | 200 | 0.32 | 3093.75 |
| 2 | 5.5 | 1 | | 9.42 | 160 | 0.5 | 3014.40 |
| 3 | 7 | 1 | | 15.3 | 95 | 0.5 | 2907.00 |
| 1 | 9 | 1 | | 25.36 | 47 | 0.4 | 2979.80 |
| 2 | 12 | 1 | | 45.14 | 25.5 | 0.43 | 2676.91 |
| 3 | 15 | 1 | | 70.5 | 10.5 | 0.38 | 1948.03 |
| 3 | 15 | 10 | | 6.28 | 120 | 0.38 | 1983.16 |
| 1 | 20 | 1 | | 125.52 | 5 | 0.45 | 1394.67 |
| 1 | 20 | 10 | | 11.78 | 53 | 0.45 | 1387.42 |
| 2 | 25 | 10 | 196.17 | 18.84 | 23 | 0.4 | 1083.30 |
| 3 | 32 | 10 | 321.45 | 31.37 | 8.7 | 0.3 | 909.73 |
| 1 | 40 | 10 | | 49.45 | 5 | 0.32 | 772.66 |
| 2 | 50 | 10 | | 77.72 | 4.3 | 0.5 | 668.39 |




Results

| VES No. | Layer depth, m | Electric Resistivity, δ Ohm, m |
|---|---|---|
| 6 | 0,0-12,0<br>12,0-30,0 | 800<br>250 |

**Contract No. GC-1701**

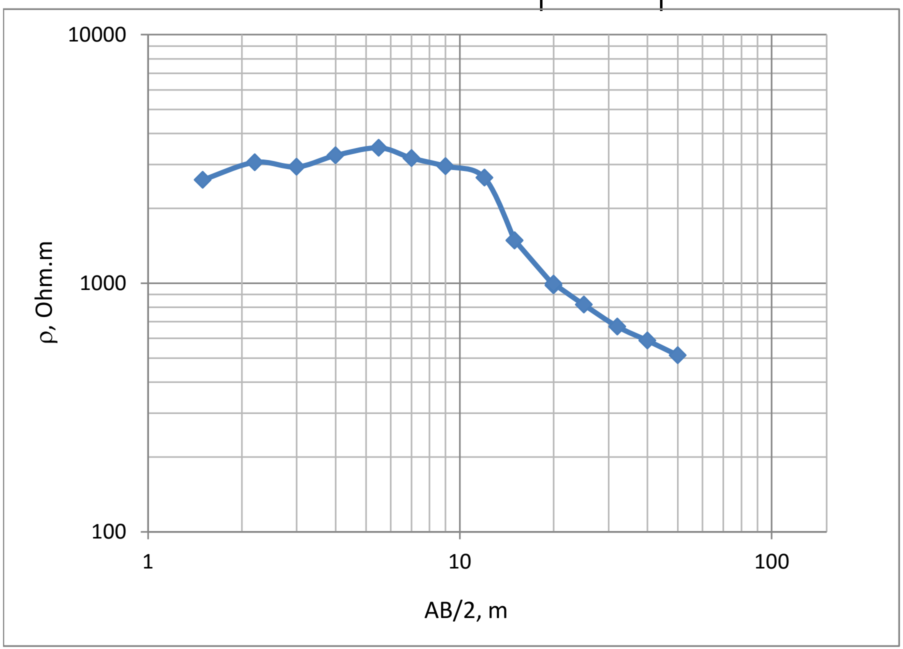
**Ptoject Name:** Provision of Geotechnical Investigation for New Road Tunnel and Overpass in Dariali Valley, Georgia

**Location:**

| X | Y |
|---|---|
| 469810 | 4730048 |

## VES No. 7

| № | AB/2 | MN | K' | K | ΔV | I | ρ |
|---|---|---|---|---|---|---|---|
| 1 | 1.5 | 1 | | 0.628 | 415 | 0.1 | 2606.20 |
| 2 | 2.2 | 1 | | 1.44 | 830 | 0.39 | 3064.62 |
| 3 | 3 | 1 | | 2.75 | 630 | 0.59 | 2936.44 |
| 1 | 4 | 1 | | 4.95 | 330 | 0.5 | 3267.00 |
| 2 | 5.5 | 1 | | 9.42 | 160 | 0.43 | 3505.12 |
| 3 | 7 | 1 | | 15.3 | 125 | 0.6 | 3187.50 |
| 1 | 9 | 1 | | 25.36 | 35 | 0.3 | 2958.67 |
| 2 | 12 | 1 | | 45.14 | 10 | 0.17 | 2655.29 |
| 3 | 15 | 1 | | 70.5 | 8 | 0.38 | 1484.21 |
| 3 | 15 | 10 | | 6.28 | 90 | 0.38 | 1487.37 |
| 1 | 20 | 1 | | 125.52 | 2.5 | 0.32 | 980.63 |
| 1 | 20 | 10 | | 11.78 | 27 | 0.32 | 993.94 |
| 2 | 25 | 10 | 196.17 | 18.84 | 10 | 0.23 | 819.13 |
| 3 | 32 | 10 | 321.45 | 31.37 | 6.4 | 0.3 | 669.23 |
| 1 | 40 | 10 | | 49.45 | 3.8 | 0.32 | 587.22 |
| 2 | 50 | 10 | | 77.72 | 3.3 | 0.5 | 512.95 |




Results

| VES No. | Layer depth, m | Electric Resistivity, δ Ohm, m |
|---|---|---|
| 7 | 0,0-12,0<br>12,0-30,0 | 950<br>250 |

**Contract No. GC-1701**

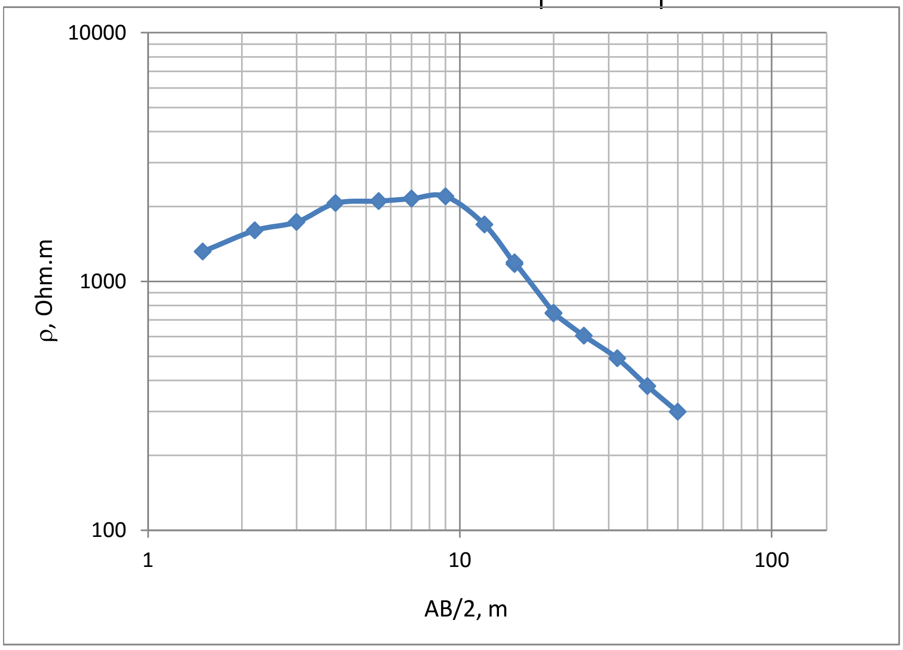
**Ptoject Name:** Provision of Geotechnical Investigation for New Road Tunnel and Overpass in Dariali Valley, Georgia

**Location:**

| X | Y |
|---|---|
| 469871 | 4730038 |

## VES No. 8

| № | AB/2 | MN | K' | K | ΔV | I | ρ |
|---|---|---|---|---|---|---|---|
| 1 | 1.5 | 1 | | 0.628 | 420 | 0.2 | 1318.80 |
| 2 | 2.2 | 1 | | 1.44 | 445 | 0.4 | 1602.00 |
| 3 | 3 | 1 | | 2.75 | 145 | 0.23 | 1733.70 |
| 1 | 4 | 1 | | 4.95 | 175 | 0.42 | 2062.50 |
| 2 | 5.5 | 1 | | 9.42 | 67 | 0.3 | 2103.80 |
| 3 | 7 | 1 | | 15.3 | 45 | 0.32 | 2151.56 |
| 1 | 9 | 1 | | 25.36 | 26 | 0.3 | 2197.87 |
| 2 | 12 | 1 | | 45.14 | 12 | 0.32 | 1692.75 |
| 3 | 15 | 1 | | 70.5 | 5 | 0.3 | 1175.00 |
| 3 | 15 | 10 | | 6.28 | 57 | 0.3 | 1193.20 |
| 1 | 20 | 1 | | 125.52 | 2.5 | 0.42 | 747.14 |
| 1 | 20 | 10 | | 11.78 | 26.5 | 0.42 | 743.26 |
| 2 | 25 | 10 | 196.17 | 18.84 | 13.8 | 0.43 | 604.63 |
| 3 | 32 | 10 | 321.45 | 31.37 | 5 | 0.32 | 490.16 |
| 1 | 40 | 10 | | 49.45 | 2.3 | 0.3 | 379.12 |
| 2 | 50 | 10 | | 77.72 | 2 | 0.52 | 298.92 |




Results

| VES No. | Layer depth, m | Electric Resistivity, δ Ohm, m |
|---|---|---|
| 8 | 0,0-9,0<br>9,0-30,0 | 960<br>210 |

**Contract No. GC-1701**

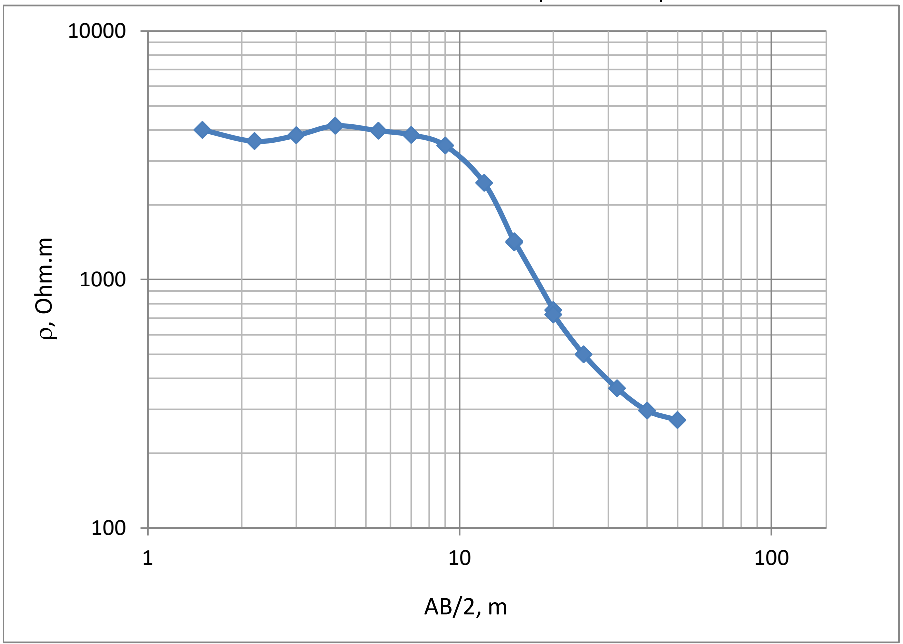
**Ptoject Name:** Provision of Geotechnical Investigation for New Road Tunnel and Overpass in Dariali Valley, Georgia

**Location:**

| X | Y |
|---|---|
| 469852 | 4730158 |

**VES No. 9**

| № | AB/2 | MN | K' | K | ΔV | I | ρ |
|---|---|---|---|---|---|---|---|
| 1 | 1.5 | 1 | | 0.628 | 700 | 0.11 | 3996.36 |
| 2 | 2.2 | 1 | | 1.44 | 250 | 0.1 | 3600.00 |
| 3 | 3 | 1 | | 2.75 | 760 | 0.55 | 3800.00 |
| 1 | 4 | 1 | | 4.95 | 470 | 0.56 | 4154.46 |
| 2 | 5.5 | 1 | | 9.42 | 295 | 0.7 | 3969.86 |
| 3 | 7 | 1 | | 15.3 | 139.8 | 0.56 | 3819.54 |
| 1 | 9 | 1 | | 25.36 | 45 | 0.33 | 3458.18 |
| 2 | 12 | 1 | | 45.14 | 26 | 0.48 | 2445.08 |
| 3 | 15 | 1 | | 70.5 | 12 | 0.6 | 1410.00 |
| 3 | 15 | 10 | | 6.28 | 136 | 0.6 | 1423.47 |
| 1 | 20 | 1 | | 125.52 | 0.9 | 0.15 | 753.12 |
| 1 | 20 | 10 | | 11.78 | 9.2 | 0.15 | 722.51 |
| 2 | 25 | 10 | 196.17 | 18.84 | 5.3 | 0.2 | 499.26 |
| 3 | 32 | 10 | 321.45 | 31.37 | 5 | 0.43 | 364.77 |
| 1 | 40 | 10 | | 49.45 | 3 | 0.5 | 296.70 |
| 2 | 50 | 10 | | 77.72 | 1.05 | 0.3 | 272.02 |




Results

| VES No. | Layer depth, m | Electric Resistivity, δ Ohm, m |
|---|---|---|
| 9 | 0,0-10,0<br>10,0-30,0 | 980<br>220 |

**Contract No. GC-1701**

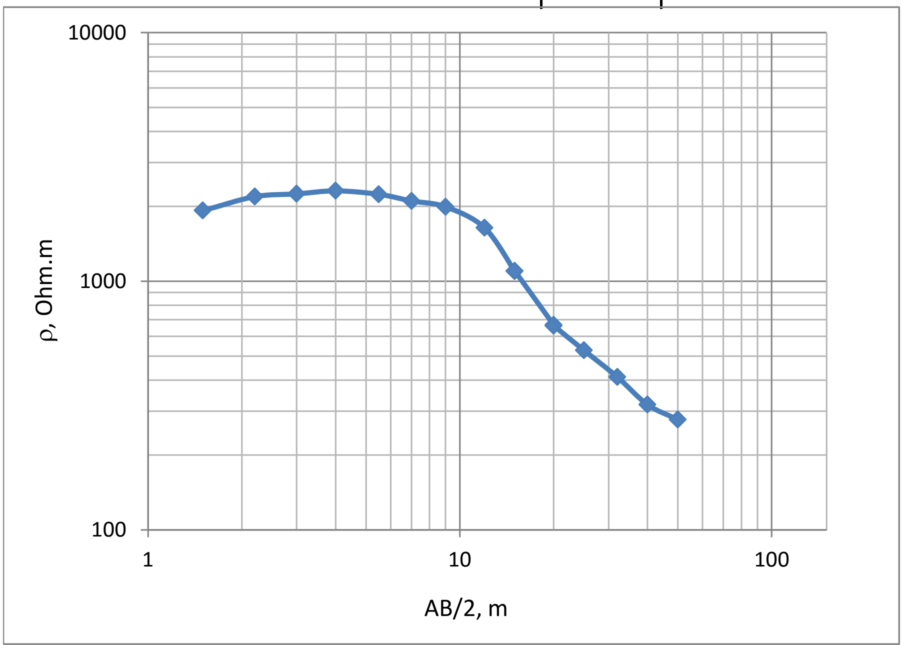
**Ptoject Name:** Provision of Geotechnical Investigation for New Road Tunnel and Overpass in Dariali Valley, Georgia

**Location:**

| X | Y |
|---|---|
| 469916 | 4730147 |

## VES No. 10

| № | AB/2 | MN | K' | K | ΔV | I | ρ |
|---|---|---|---|---|---|---|---|
| 1 | 1.5 | 1 | | 0.628 | 245 | 0.08 | 1923.25 |
| 2 | 2.2 | 1 | | 1.44 | 760 | 0.5 | 2188.80 |
| 3 | 3 | 1 | | 2.75 | 980 | 1.2 | 2245.83 |
| 1 | 4 | 1 | | 4.95 | 560 | 1.2 | 2310.00 |
| 2 | 5.5 | 1 | | 9.42 | 190 | 0.8 | 2237.25 |
| 3 | 7 | 1 | | 15.3 | 110 | 0.8 | 2103.75 |
| 1 | 9 | 1 | | 25.36 | 110 | 1.4 | 1992.57 |
| 2 | 12 | 1 | | 45.14 | 80 | 2.2 | 1641.45 |
| 3 | 15 | 1 | | 70.5 | 42 | 2.7 | 1096.67 |
| 3 | 15 | 10 | | 6.28 | 473 | 2.7 | 1100.16 |
| 1 | 20 | 1 | | 125.52 | 17 | 3.2 | 666.83 |
| 1 | 20 | 10 | | 11.78 | 180 | 3.2 | 662.63 |
| 2 | 25 | 10 | 196.17 | 18.84 | 42 | 1.5 | 527.52 |
| 3 | 32 | 10 | 321.45 | 31.37 | 21 | 1.6 | 411.73 |
| 1 | 40 | 10 | | 49.45 | 5.8 | 0.9 | 318.68 |
| 2 | 50 | 10 | | 77.72 | 2.5 | 0.7 | 277.57 |




Results

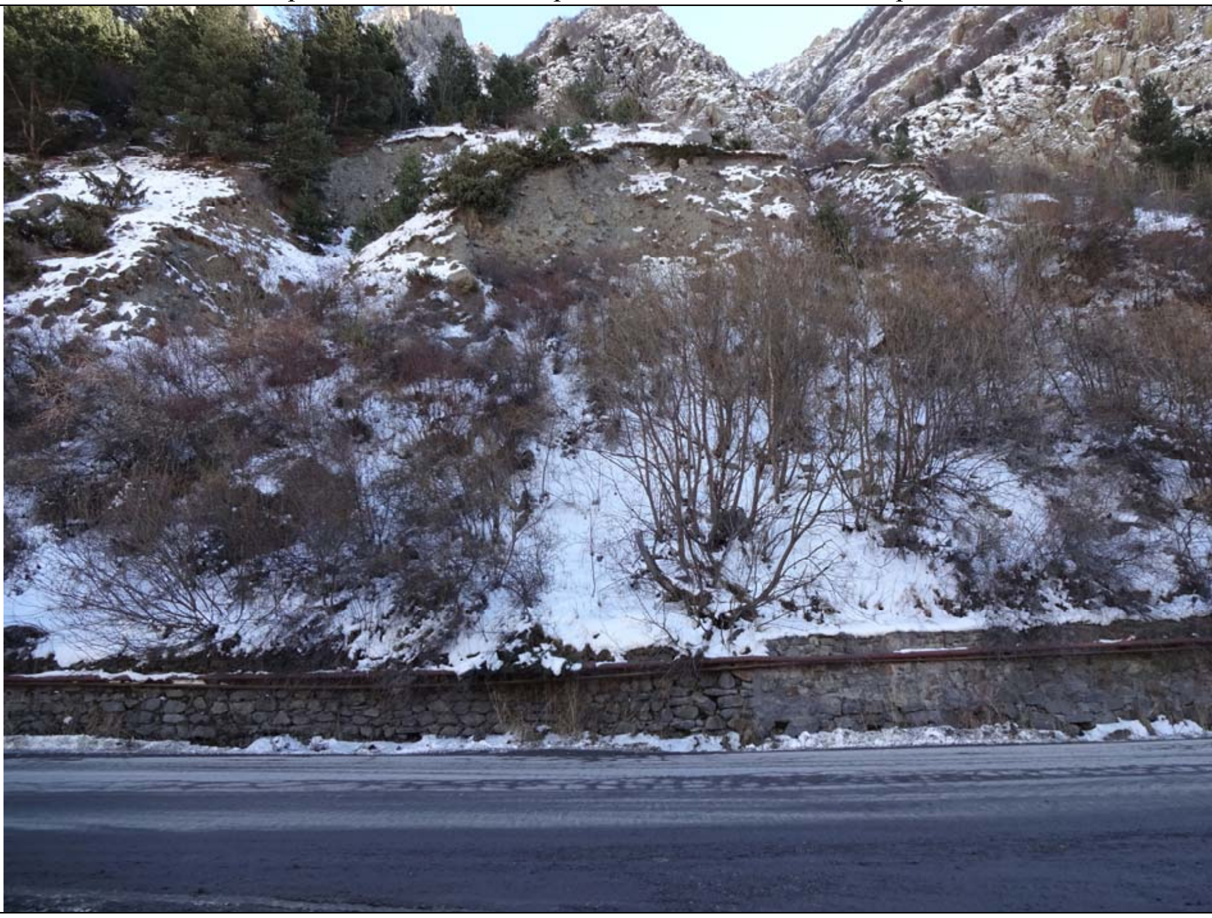
| VES No. | Layer depth, m | Electric Resistivity, δ Ohm, m |
|---|---|---|
| 10 | 0,0-10,0<br>10,0-30,0 | 970<br>190 |

## ფოტოდოკუმენტაცია

**პროექტის დასახელება:** GC-1701. საქართველოში, დარიალის ხეობაში გზის ახალი გვირაბის და ესტაკადის გეოტექნიკური გამოკვლევა
Project name: GC-1701. Provision of Geotechnical Investigation for New Road Tunnel and Overpass in Dariali Valley, Georgia

ფოტო-1. გვირაბის სამხრეთი პორტალის უბანი
Pic-1. The south portal site of the tunnel

**ფოტო-2.** გრუნტების ელექტროზონდირება გვირაბის სამხრეთი პორტალის უბანზე
Pic-2. Electrical Resistivity Test at the south portal site of the tunnel

| ფოტოდოკუმენტაცია |
|---|
| **პროექტის დასახელება**: GC-1701. საქართველოში, დარიალის ხეობაში გზის ახალი გვირაბის და ესტაკადის გეოტექნიკური გამოკვლევა<br>Project name: GC-1701. Provision of Geotechnical Investigation for New Road Tunnel and Overpass in Dariali Valley, Georgia |
| **ფოტო-3.** კლდოვან ქანებზე დალექილი კოლუვიურ-პროლუვიური ნალექები, გვირაბის სამხრეთი ნაწილის უბანზე<br>Pic-3. Colluvuial-proluvial sediments deposited on rocks at the south portal site of the tunnel |
|  |