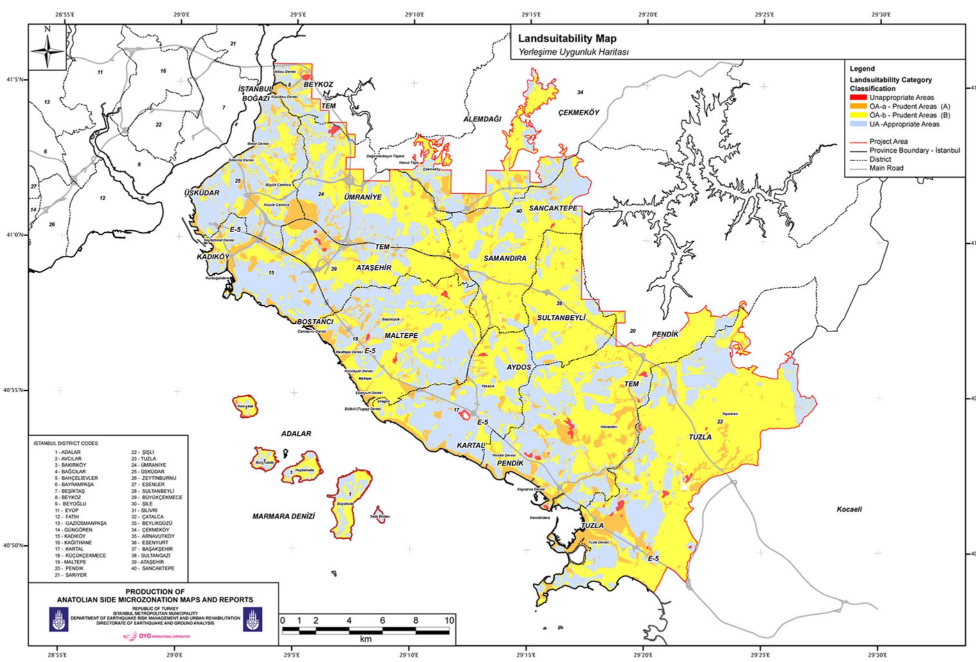
T.R.
İSTANBUL METROPOLITAN MUNICIPALITY
DEPARTMENT OF EARTHQUAKE RISK MANAGEMENT AND URBAN DEVELOPMENT
DIRECTORATE OF EARTHQUAKE AND GROUND ANALYSIS

# EXECUTIVE REPORT

## PRODUCTION OF MICROZONATION REPORT AND MAPS FOR ASIA SIDE




NOVEMBER 2009

OYO INTERNATIONAL CORPORATION

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## ABBREVIATIONS

| | |
|---|---|
| İ.B.B. | Istanbul Metropolitan Municipality |
| M.T.A. | Mineral Research and Exploration |
| OIC | OYO International Corporation |
| AYM | Disaster Managment Center |
| İSKİ | İstanbul Su ve Kanalizasyon İdaresi |
| DSİ | Devlet Su İşleri |
| C.B.S. | Geographic Information System |
| GRM | GRM İletişim ve Bilişim San. Tic. Ltd. Şti. |

## PREFACE

According to the order which was placed by “Turkish Republic İstanbul Metropolitan Municipality Department of Earthquake Risk Management and Urban Development Directorate of Earthquake and Ground Analysis ”, OYO International Corporation headquartered in Japan (OIC) has conducted “Production of Anatolian Side Microzonation Maps and Reports” to make a microzonation study in Asian side of Istanbul City.

OIC has assigned Tatsukichi Tanaka as a project manager. And a study team, consisted of Jananese engineers and Turkish subcontractors, was organized. The study team started the investigations and analyses from August 2007 to December 2009.

The survey area was approximately 509km$^2$ of Asian side of Isutanbul City. Geological site observations, drilling surveys, geophysical surveys and laboratory tests were conducted in this project area which were carefully planned. Huge volume of the data of soil and rock properties were acquired. According to these data, the study team made various hazard maps such as Ground Shaking Map, Liquefaction Hazard Map, Landslide Hazard Map, Flooding Hazard Map and etc. Finally, the survey team summarized all results as Land Suitability Map.

There is no other similar cases of making such a Land Suitability Map based on carefully planned surveys and huge volume of the data in the past. This study will be an outstanding study in the world on the disaster prevention point of view. We would like to express our respect that İBB planned this project and set it into action.

For finalizing the project, OIC prepared the reports and the maps. We hope that those reports and maps will contribute to future disaster mitigation plannings or others.

Finally, we wish to express our sincere appreciations to İBB’s cooperation and suggestion for us to go our tasks forward smoothly.

December, 2009

Tatsukichi TANAKA
President and Project Manager
OYO International Corporation

## 1. THE OBJECTIVE AND CONTENT

Within the scope of Istanbul Metropolitan Municipality, Directorate of Earthquake and Ground Analysis; “MICROZONATION MAPS AND REPORTS OF ANATOLIAN SIDE” work which is the second stage of Microzonation Studies conducted in the borders of Istanbul Provincial area, was started on the date of 20.07.2007 by the contract signed between Istanbul Metropolitan Municipality and OYO International Corporation (Head office is in Japan) Turkey Branch, and on the date of 10.11.2009 all site and office studies were finished.

This study contains the subjects indicated in the Technical Specification which is the addition of the work contract, the subjects belonging to the Microzonation studies that are specified in Format-4 in 19.08.2008 dated and 10337 numbered General Directorate of Disaster Affairs notice addition and the subjects specified in other law, regulations and circulars.

Aim of the study is the determination of geological, geotechnical, geophysical features of Anatolian Side, Istanbul Provincial and the areas of Anatolian Side with different hazard potentials in terms of earthquake effect and local ground conditions, creation of the solution suggestions by analysing the detected problems, then preparing the required map productions in the light of the obtained datas and finally by these products, preparation of 1/2000 printout scaled ”Land Suitability Maps” which will constitute the basis for the Construction Plan.

The main aim of the preparation of all Microzonation products including land suitability maps too which were obtained by this study, and the reports belonging to these products;

1) To form basis for all type of featured (City Planning, Application, Piecemeal etc.) and all type of scaled (1/25000, 1/5000, 1/2000, 1/1000) construction plans,

2) To provide data for Urban Transformation Projects which are considered to be conducted basing on liquidation, rehabilitation, renewal strategies in built-up areas with hazard risk, and to direct the priorities,

3) To form basis for Harm Reduction Plans that will be prepared,

4) To provide data and to direct the feasibility studies in the designing stage of sizable investments and engineering structures (tunnel, subway, underground strorages, viaduct etc.),

5) To provide data and offer suggestions to the foundations such as ISKI, DSI about the subjects such as underground waters and rainwash-flooding,

6) To provide preinformation for the Soil Survey Reports which must be prepared as aimed at application before all type of construction and to direct the details of the study that will be conducted,

7) And to form geographical data base about the subjects such as insurance regulations etc.

The Study Area contains all parts of Kadıköy, Ataşehir, Ümraniye, Adalar, Sancaktepe, Sultanbeyli, Maltepe, Kartal, Pendik, Tuzla ve Çekmeköy counties except water basin and forest lands, south parts of Beykoz County and its total area is 509,60 km$^2$. Whole area consists of 1/2.000 scaled 452 sheets, 1/5.000 scaled 134 sheets.

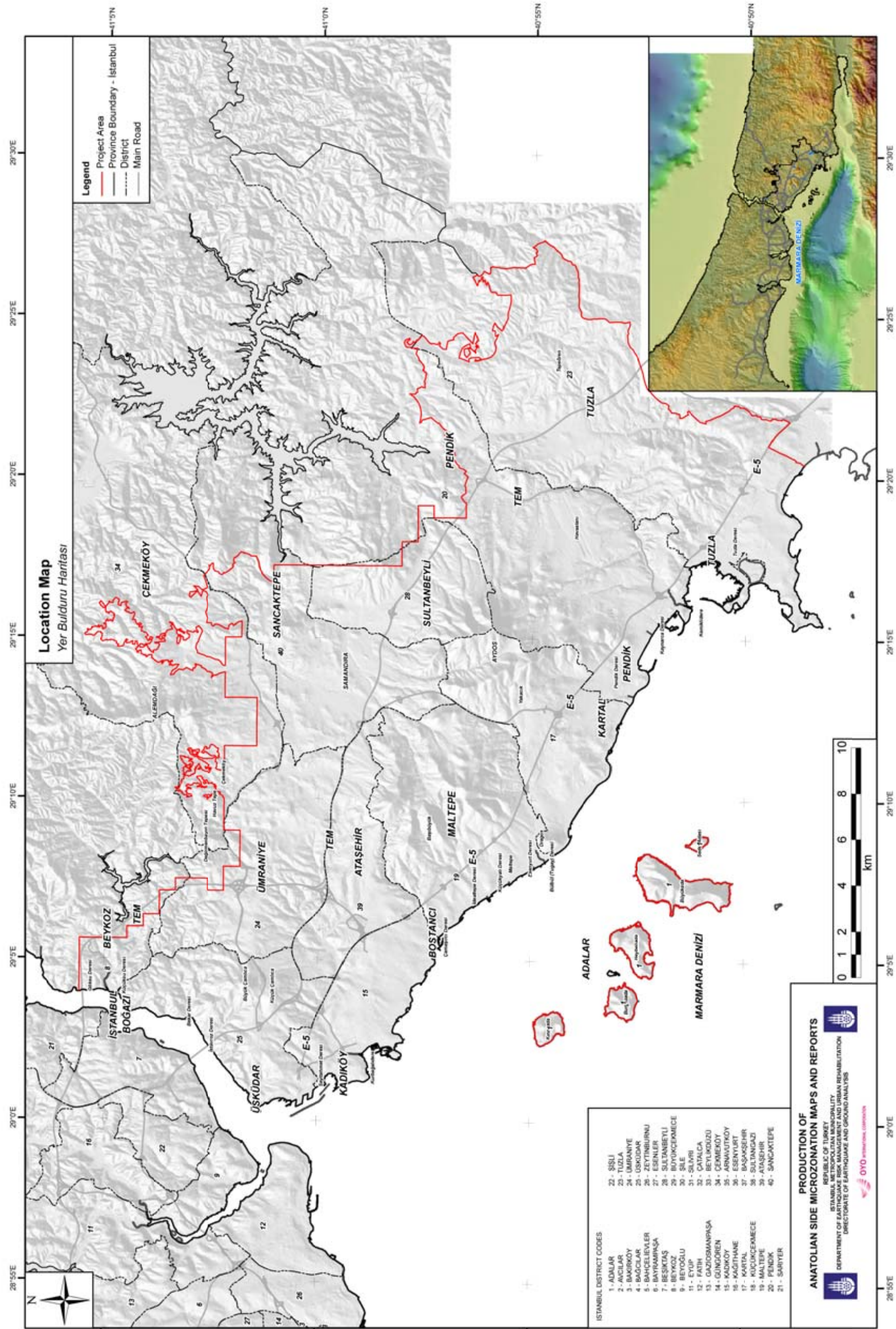



**Figure 1.1 Location of the Study Area**

# 2. WORK METHODS

## 2.1 Planning and Organization

In the scope of microzonation studies, by forming project work groups the task distributions of all groups were defined and microzonation evaluation team was organized by the participation of each group head and one each member from each group. The work group in which the Project Manager presided this evaluation team as well, carried out the production of microzonation maps by evaluating all group studies finally. During the entire study, 98 engineers and technical staff, 280 technicians, borer, deputy borer and employee participated in the project.

Also each stage of the studies were inspected on site by the control organization which consists of 13 people commissioned in IMM Directorate of Earthquake and Ground Analysis.

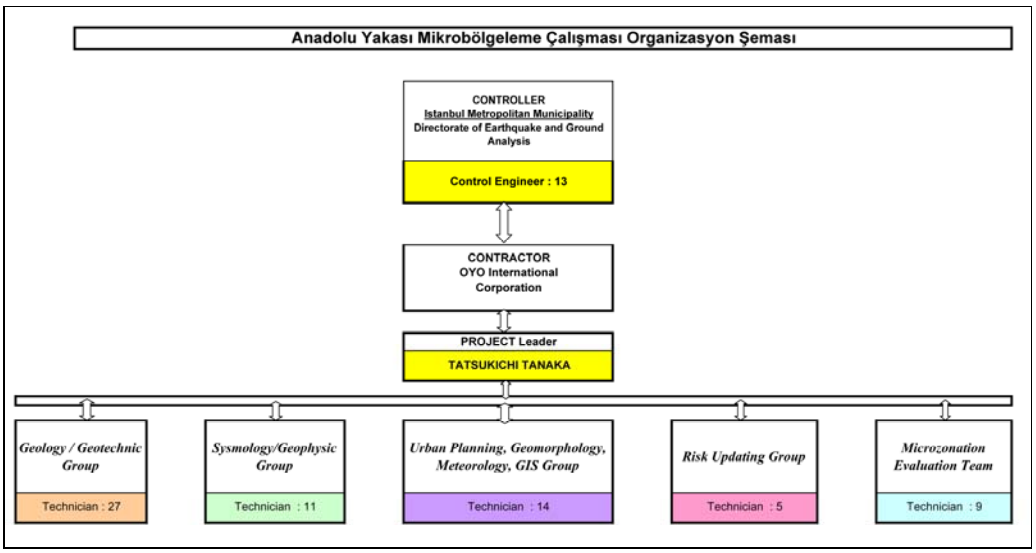



**Figure 2.1 Work Organization**

## 2.2 Data Supply

In the project area, because of they form basis in both site studies and office studies, the datas producted on numerical and paper environment in the previous years by various corporations and establishments, were collected and entered into the data system which was developed for the project. Some major datas provided in this scope, were given with general headings as below.

1. Different scaled base maps producted by İBB Directorate of Cartography (Base maps, Satellige Image, Aerial Photograph, Administrative borders, etc.)

2. The inventory (As-Built) data sets provided by infrastructure corporations such as İSKİ, İGDAŞ, Nato, Telekom, etc.

3. The statictical datas such as precipitation, flow, evaporation etc. which are based on long years and were provided from General Directorate of Meteorology and İSKİ

4. 1/1.000 and 1/5.000 scaled Housing Plans, Land Use Maps obtained from İBB Directorate of Urban Planning.

5. 1/5.000 scaled Geology, Land Suitability Studies conducted at İBB Directorate of Earthquake and Ground Analysis.

6. 1/1.000 scaled Land Suitability Studies conducted by County Municipalities situated in the project area.

## 2.3 Site and Office Studies

For the purpose of defining different hazard potential areas of the project area in terms of local ground conditions both with earthquake effect and without earthquake effect, by using geological, geotechnical, geophysical methods, different studies were conducted and the datas that will characterize the area were compiled.

### 2.3.1 Gridding

Microzonation studies are conducted with the approach of dividing study site into specified equal cell dimensions and obtaining adequate soil information about each cell area. These cells named as grids are designed as quadratic areas in order to prevent calculation and evaluation problems. Therefore field that is to be studied is separated into pre-specified equal grid sizes. Grids that cover Istanbul Province border in ‘‘250mx250m’’dimensions and produced within the scope of Making of Microzonation Reports and Maps-European South – Project (1.Stage study) are used while separating study field into grids. Accordingly, there is a total of 8788 grids in Anatolian side study field. (16 grid per 1 km$^{2)}$

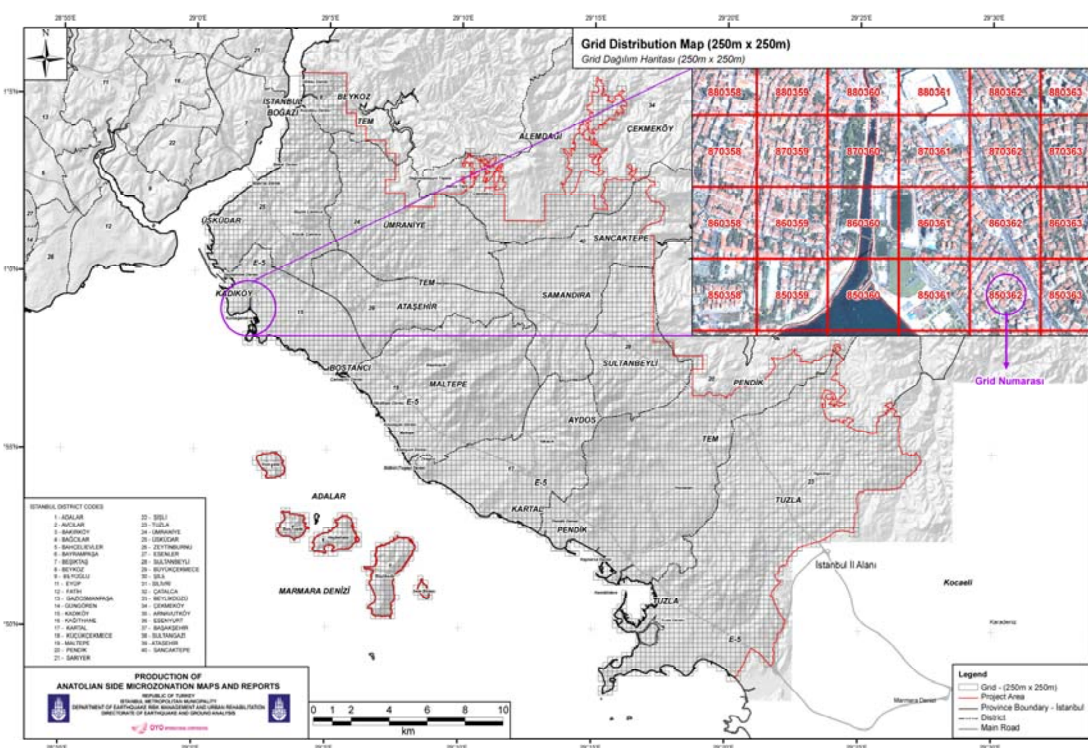



**Figure 2.2 Grid Distribution Map**

### 2.3.2 Field, Laboratory and Office Studies

#### 2.3.2.1 Mechanical Boring Studies

Studies that require most workforce and time among field studies are boring studies. For this reason a total of 5.029 boreholes are opened in different depths for various purposed given in detail below, and total boring tool depth (lentgh in metres) is 118.047 meters

**Chart 2.1 Mechanical Boring Type Distribution According to Purpose**

| Boring Type | Purpose | Spot Number | Total Amount (m) |
|---|---|---|---|
| Normal | Gathering information about areas geological structure | 4436 | 98681,40 |
| Deep | Detection of bedrock depth, sratigraphy and structural elements | 122 | 11594,50 |
| Liquidization | Presence, depth and risk level detection of liquidization problem | 433 | 6683,00 |
| Landslide | Identification of landslide areas and solution of their mechanisms | 10 | 227,00 |
| Fault line | Studies of structural elements | 9 | 317,50 |
| Artificial Filling | Expansion, thickness and stability studies of controlled and uncontrolled fillings | 19 | 544,00 |
| | **Grand Total** | **5.029** | **118.047,00** |

Criteria given below are used while detecting boring locations and depths;

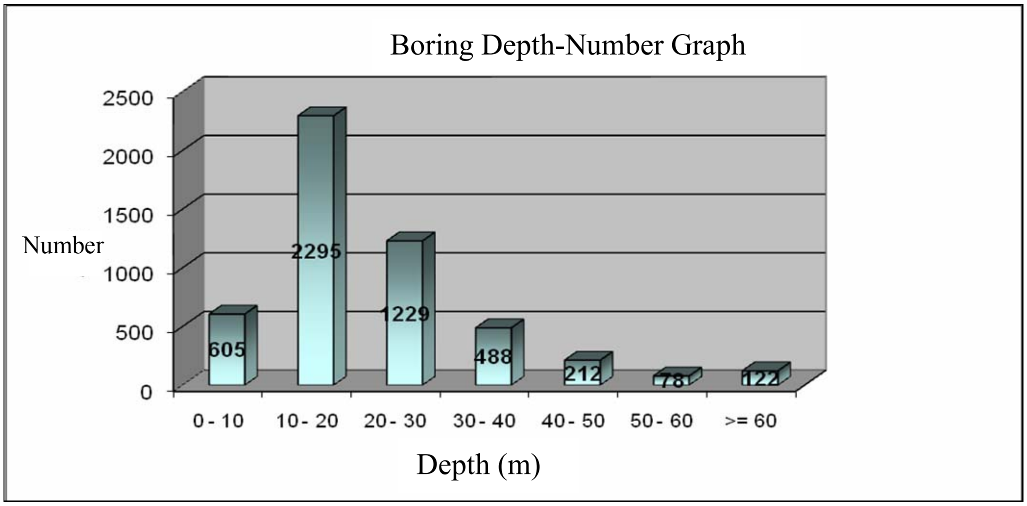
- Single normal boring per each grid is planned in the areas where units exhibiting soil property partake. Nevertheless, in situations when homegeneity progresses into wide areas despite soil environment presence, boring distances are done densely to provide adequate data and areal representation.

- "In areas where ''Rock'' property possessing units take place, generally a sum of 4-6 normal borings per ***1km²*** according to rock's having homogeneous or heterogeneous property and sizes of surfacings are planned. Less frequent borings for rocks that have adequate surfacing, covering wide areas and exhibiting uniform properties are planned, while more frequent borings for rocks that are expected to exhibit significant geomechanic property and/or surface thickness difference are planned. In areas that are surfaced by weathered rocks, one per 2 grids and more or less borings are planned considering weathering level, deph and surfacings currency.

- Borings more than one per single grids are planned for detecting buried valleys and channel fillings geometry and for areas where soil type with high potential of liquidization is widespread and for cases when it is obligatory to specify base topography in detail.

- While soil borings and weathered borings among borings within the scope of the Project are predicted to be opened in min 30m depth, boring depths of units possessing uniform physical features(rock borings) and in Hard rock property are planned as average of 10-15m. However, boring depths are increased in necessary cases depending on rock's weathering level and rock class. Depth change distribution of the borings are given in below graphic. As a result of rock unit's surfacing on 61% of study field (Figure 2.3) and liquidization borings being max. 20 m, boring depth distribution in borings is intensified at the 10-20m gap.

**Chart 2.2 Boring Depth-Number Graph**




Every boring made in the microzonation study which is performed by 250 X 250 m cells, is accepted to represent an area of 250m. Analysis result made by represantative circles of 250m with the condition of regarding boring locations as center accordingly are given in Figure 2.4 Boring Studies Densiy Map. As it can be understood form this anaysis, borings are observed to be adequately representing study field in convenience with both 250m grid approach and areal expansion. There are some areas observed in the figure which are not represened by borings. These areas are dense forest, airport and miliary areas.

Additionally, it is observed that in regions(possible problematic areas) where soil environments exhibit expansion borings are more frequent and in rock regions they are relatively less frequent compared to Figure 2.3.

It should not be forgotten that unit area study density increases when CPT tests that are conducted in order to support boring studies and geophysics studies are refleced to this analysis.

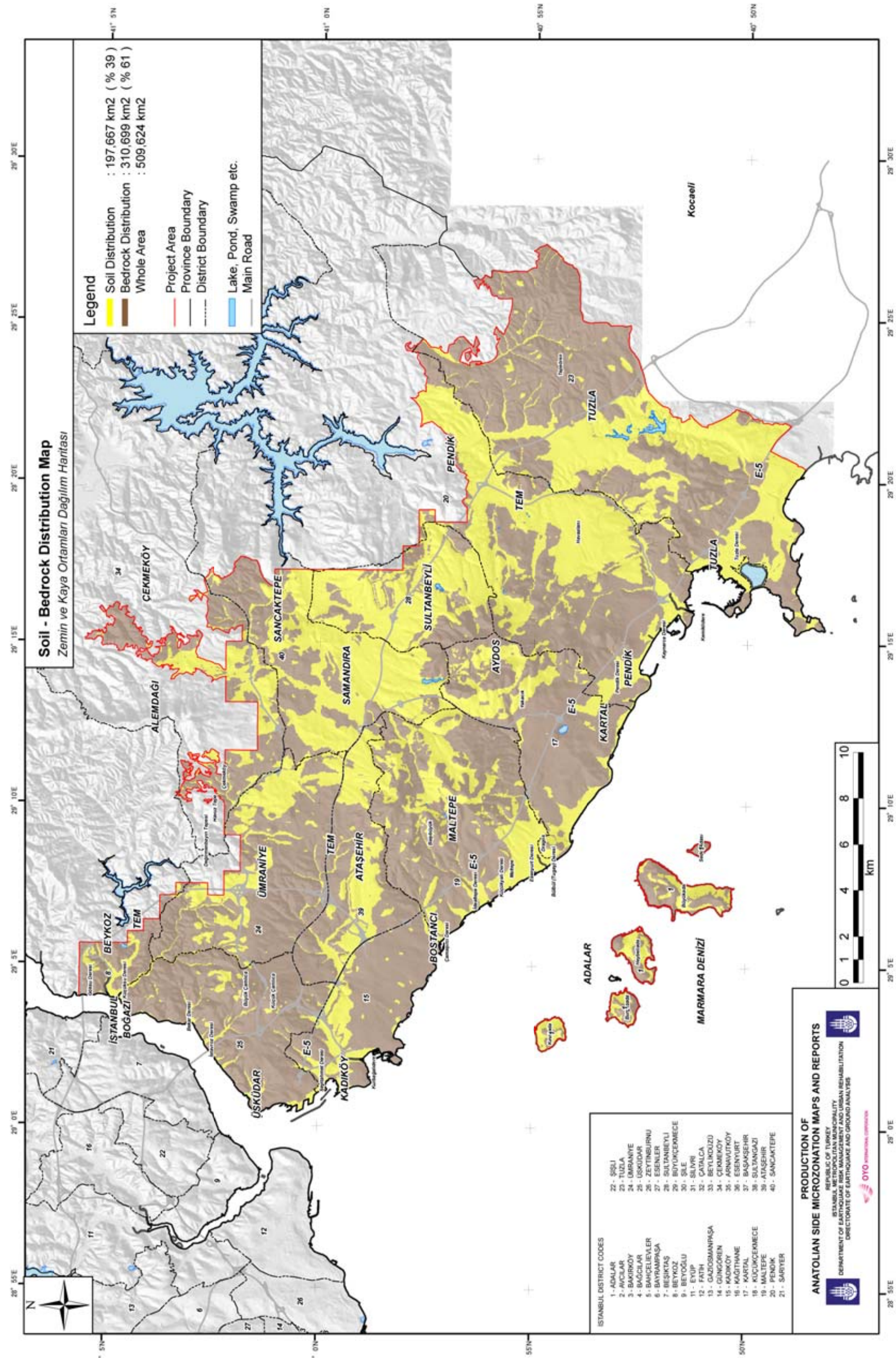



**Figure 2.3 Soil - Bedrock Distribution Map**

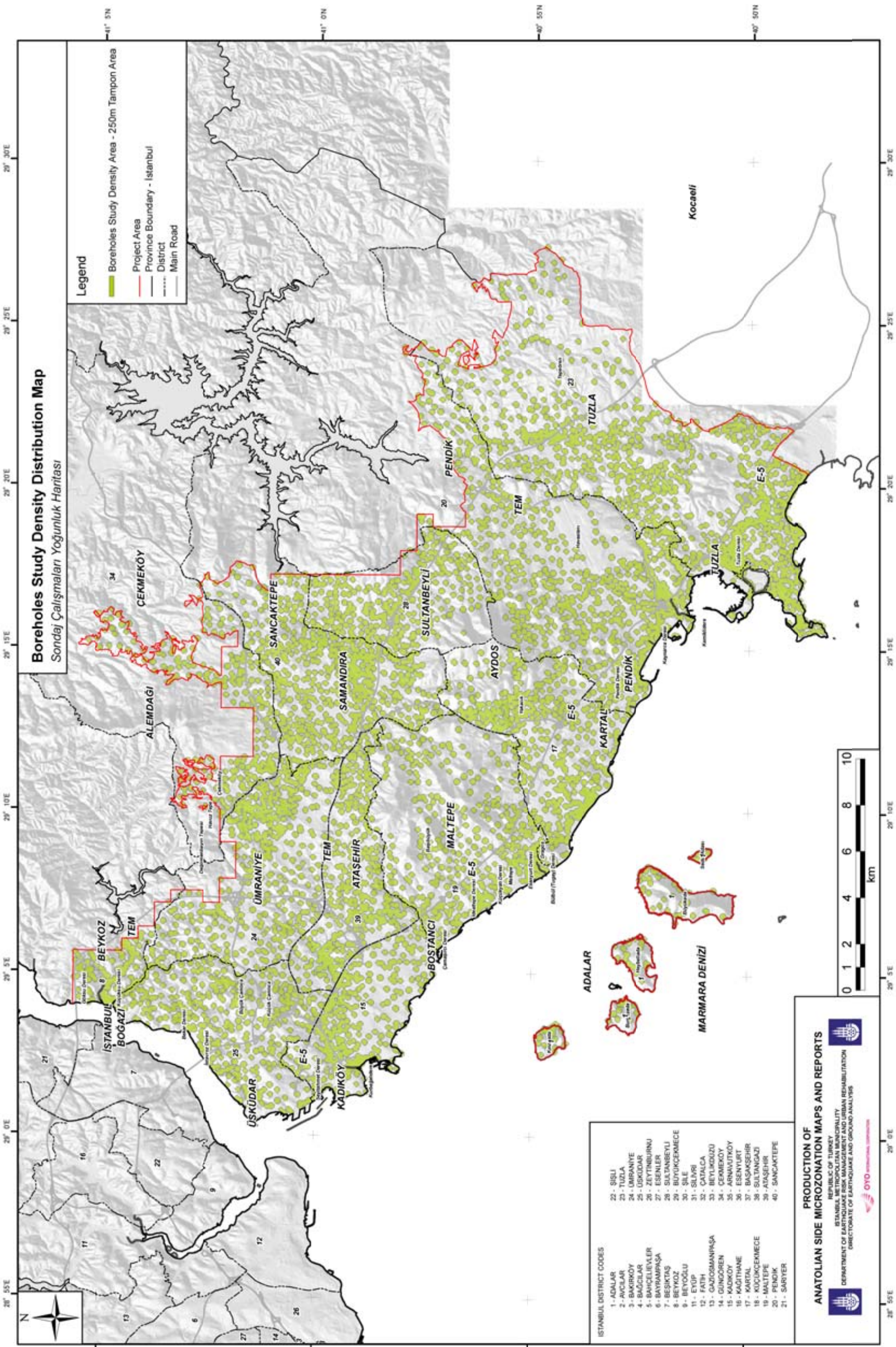



**Figure 2.4 Boreholes Study Density Distribution Map**

#### 2.3.2.2 CPT (Conic Penetration Test)

CPT studies are made in addition to the boring studies conducted in the areas that are detected to possess liquidization risk by analyses made in the light of the data obtained by boring studies. Pre-drilling is made in order to eliminate material on the surface that can prevent the start of the test while making these studies and to lower CPT kit into the level to be tested. A total of 377 CPT studies given in detail below are made within the scope of the study. CPT locations can be seen in Figure 2.5.

**Chart 2.3 CPT Studies**

| CPT | Total amount (m) |
|---|---|
| Pre Drilling | 823,42 |
| Measurement Drilling | 3252,8 |
| Total Drilling | 4076,22 |

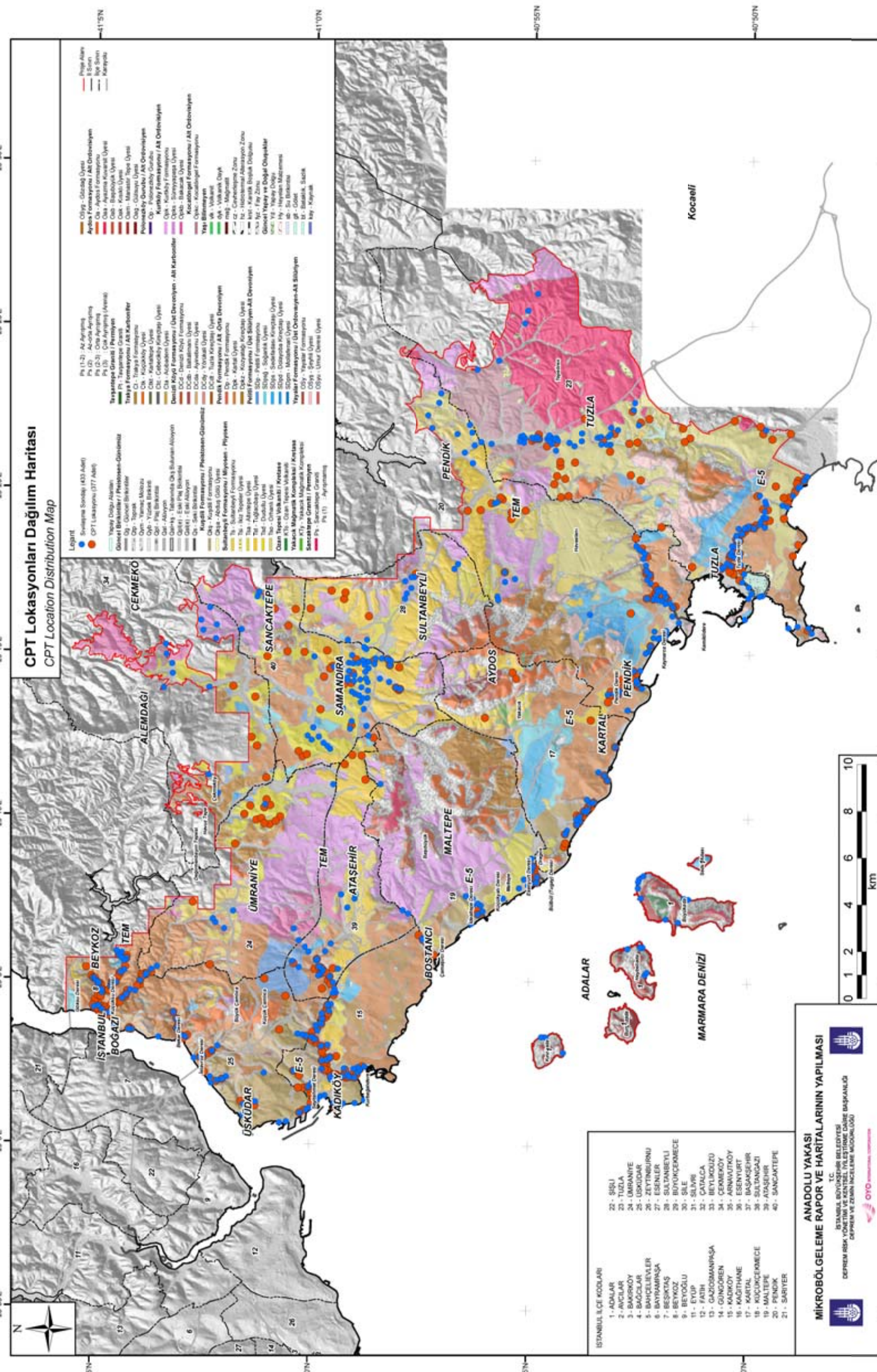



**Figure 2.5 CPT Locations Distribution Map**

#### 2.3.2.3 Geophysics Studies

In addition to boring studies in the project site, geophysical studies at 4807 locations with various purposes are performed. Details about the geophysics studies made in study field are given below.

**Chart 2.4 Geophysical Studies**

| Geophysical Studies | Study Number | Total amount (m) |
|---|---|---|
| Seismic Refraction Line | 4132 | 435.093 |
| Seismic Reflection Line | 8 | 14.105 |
| 2D-ReMi | 53 | 19,361 |
| 2D- Electricity Resistivity | 80 | 22.218,75 |
| Micro-tremor | 30 | - |
| PS Logging | 504 | 2.928 |

#### 2.3.2.4 Laboratory

Besides on-site monitoring of soil's engineering properties during boring works, a total of 26.763 SPT (disturbed sample), and 2.312 UD (undisturbed sample) samples are taken for laboratory tests.

These samples obtained during field studies are evaluated and tested in laboratory environments. Contents and amounts of these tests are displayed in Chart 2.5. A total of 90.088 tests are conducted on soil environment samples while a total of 622 tests are conducted on samples provided by rock environments. Additionally, 183 age determination tests and experiments are conducted on appropriate examples among these samples.

**Chart 2.5 Laboratory Experiments and Tests**

| Soil Mechanics Tests | | Rock Mechanics Tests | | Age Determination Tests | |
|---|---|---|---|---|---|
| **Test Name** | **Test Number** | **Test Name** | **Test Number** | **Test Name** | **Number** |
| Water Content | 29.072 | Physical Index | 242 | Conodont | 77 |
| Atterberg Limits | 21.608 | Triaxial Compression | 143 | Ostracod | 75 |
| Sieve Analysis | 29.071 | Uniaxial Compression | 88 | Palinology | 23 |
| Hydrometer Analysis | 6.867 | Indirect Pulling | 149 | Radiometrical (C14) | 8 |
| Consolidation | 1.339 | | | | |
| Swelling Pressure | 1.339 | | | | |
| Triaxial Compression | 214 | | | | |
| Uniaxial Compression | 572 | | | | |
| Direct Shear | 6 | | | | |

In addition to all these studies, measurement of energy losses related to various parameters during SPT tests, observational field studies and mapping, discontinuity measurements in mostras, opening trenches and measurements of underground water level in holes are other studies performed within the context of field.

#### 2.3.2.5 Office Studies

Synchronously with field studies performed, office studies such as entering field data to computer environment, compiling of the data gathered from agency and institutions, making analyses required for the preparation of the maps and examining analyses results with mapping are carried out. All of the data and maps produced during this process are prepared in ESRI/ArcGIS environment. Existing 1/1000 scaled belonging to 2008 and 1/5000 scaled belonging to 2005 maps constitute a base for all of the maps. Data obtained from agency and institutions and laboratory works are checked by interface software during uploading process to databases. After the completion of uploading and checking, analyses are made by program code and particles (ArcGIS VBS, Model Builder, Python, VB) that are developed in GIS environment and results of the analyses are preapared in different scale and page sizes.

A total of 13 main product maps produced within the context of the project and report details belonging to these units are given in below charts.

**Chart 2.6 Scale and Numbers of The Maps Produced**

| No | Map Name | Scale | Number |
|---|---|---|---|
| 1 | Geology | 1\2000 | 452 |
| 2 | Structural Geology | 1\5000 | 134 |
| 3 | Engineering Geology | 1\2000 | 452 |
| 4 | Landslide | 1\2000 | 253 |
| 5 | Liquidization | 1\2000 | 320 |
| 6 | Avs 30 | 1\5000 | 134 |
| 7 | Soil Classification NEHRP | 1\2000 | 452 |
| 8 | Soil Classification Euro Code | 1\2000 | 452 |
| 9 | Soil Classification Earthquake Regulations | 1\2000 | 452 |
| 10 | Earthquake | 1\5000 | 134 |
| 11 | Hydrogeology | 1\5000 | 134 |
| 12 | Settlement Convenience | 1\2000 | 452 |
| 13 | Flooding | 1\5000 | 58 |
| **Total Sheet Number** | | | **3879** |

In addition a total of 85 mid-product maps (Artificial filling, Karsting, Rock Class, Bedrock Depth, etc.) with various scales (1/150.000 and 1/40.000)to use during main product maps analysis and production are prepared.

**Chart 2.7 Main and Additional Report Page Numbers**

| Report Names | Page Number |
|---|---|
| Microzonation Main Report | 870 |
| Geology | 216 |
| Geophysics Studies | 219 |
| Flooding | 40 |
| Mass Movements | 250 |
| Hydrogeology | 91 |
| Artificial Filling | 19 |
| Geotechnics Purpose Lab. Tests | 55 |
| Earthquake Damage Report | 202 |
| 3D Data Production Report | 185 |
| Executive Summary Report | 71 |
| **Total Page Number** | **2218** |

# 3. MICROZONATION SUDIES AND RESULT PRODUCTS

## 3.1 Geoorphological Comments

Distinctive geomorphologic feaure attracting atenttion in Istanbul Anatolian Side is the presence of relatively high plains and hills rising from among them described as mountains such as Kayışdağı, Aydos Mountain, Alemdağ. It can be clearly observed especially when approached to the Black Sea shore that the highly plains are surfaces that remain from peneplain. The formation of aforementioned hills is about the presence of hard rocks that resisted to the weathering during the development of peneplain, quartizite in particular. Peneplain develops into the what is now Black Sea, and formed by streams which have high weathering power, possess seasonal braided beds that develop in the pediment feature area taking place in the high altitude area of Marmara Sea. Pediment is understood to be developed at the beginning of Miocene.

The breaking of mentioned pediment starts when the high altitude are in Marmara Sea region collapsed in the later times of Middle Miocene, leaving its place to a shallow inland sea. Regions neighbour to Marmara are affected by this collapse, drainage network in areas neighbour to the collapse region from North start to move South.

Drainage Networks weathering power increases by the Marmara concavity's rapid start to become deeper in Late Miocene – Early Pliocene, yet because of substantially high water level presence in base level forming Marmara it can not dig into deeps a this period. One of the greatest effects of this period on Anatolian side geomorhpological features is that closed concavities where today Sultanbeyli Formation partakes developed apart from Marmara concavities. Asthenospheres formed by existing NE-SW and NW-SE shearing faults and these closed concavity areas collapsed in newly developing expansion tectonic are generally filled by low energy stream and shallow lake sediments. (Figure 3.1)

Deep chipping of valleys in the research area and the movement of water linet o the Black sea on the other hand is because of Marmara's approximaely 100m descending compared to today. Rapidly descending base level leads to stream's burial starting from their estuaries forming ''V'' shape valleys. Entrenched meanders are also part of this period. Base level that rises in interglacial periods leads to drowning of valleys by sea, and Kuşdili Formation's sediments that belong to estuary environment accumulate in these areas tranquil, low energy environment conditions. Talus with similar features are protected from wave energy by natural barriers like ridge, hill etc., yet they also gravitate in lagoon environments that are connected to sea. For example, Rahmanlar plain partaking on the souh of Dragos ridge includes talus representing such kind of environments. Stream deposits with approximately 5-10m thickness accumulation period starts on aforementioned estuarties as a result of streams bringing material and this process continues today as well.

Widespread happenings of marine terraces belonging to anthropogene in Marmara shore shows that Marmara region is totally ascending altough most probably slower nowadays. To exemplify, Kuşdili Formations estuary type clays are cut in 440424N-1 No. boring started on 24.m altitude of Pendik brook valley's 1,5 km flow over within Pendik province boundaries 10 m from the start and in 420424N-1 No. boring up to 19m depth. The base of Kuşdili Formation which is expected to be gravitate below sea level is 19m high from sea level and this supports the thesis that Marmara Region continues tor ise in Holocene.

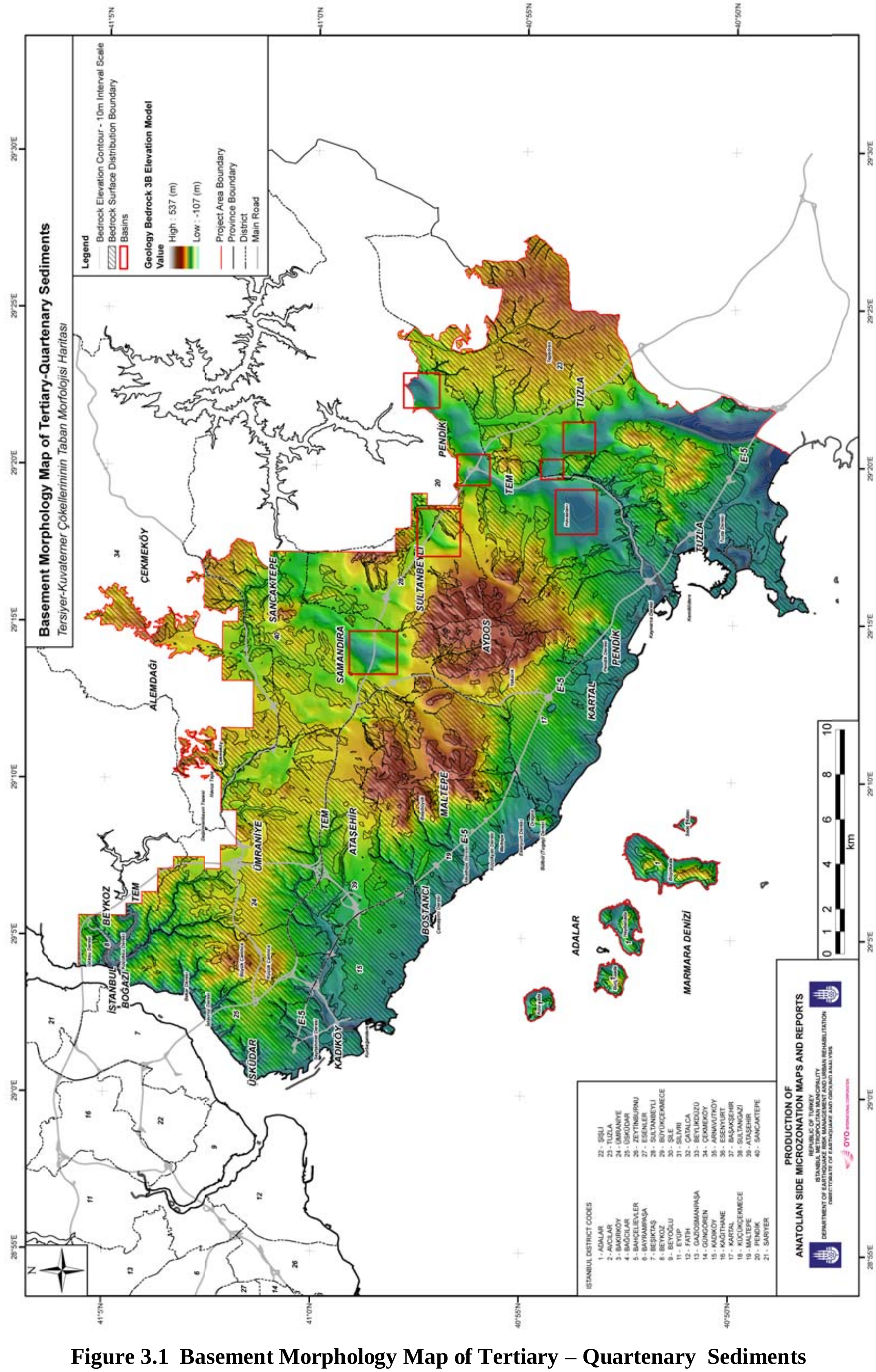
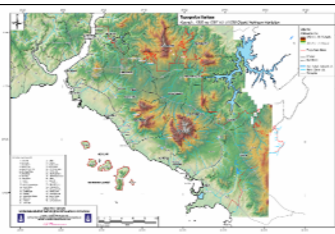


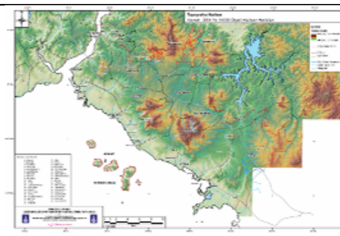

**Figure 3.1 Basement Morphology Map of Tertiary – Quartenary Sediments**

## 3.2 3D Altitude Topographical Data Sets Development

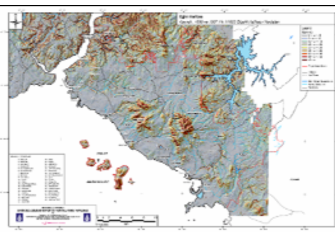
3D altitude model related to Project site within the context of the study is developed as part of ‘‘Development of Topographical Data Set that will be used in Topographic Analyses Aimed at Soil Risk Evaluation’’ work. The work is done within whole of Istanbul Metropolitan Municipality (İBB) province border. All of the geographic bases(existing ortophotography maps, satellite images, etc. of different production years and scales) and data sets that are produced by three dimensional or have third dimension (altitude) information and are in digital (computer environment) environment are used within these area. After related data sets are exposed to several filtration (topographic and non-topographic) and clarification (error and errorless) processes, data sets required for topographical analyses are produced. By using these data sets 3 dimensional altitude, slope, aspect, hillshade and stereo image maps with 1m and 5m resolutions are prepared. Obtained productions are shown in Figure 3.2.



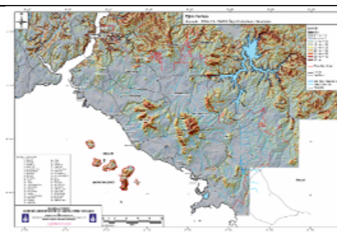
***3d Altitude Map with 1m Resolution***



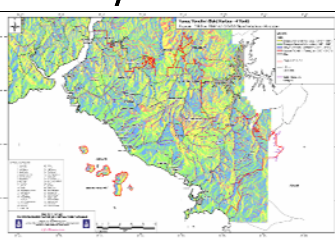
***3d Altitude Map with 5m Resolution***



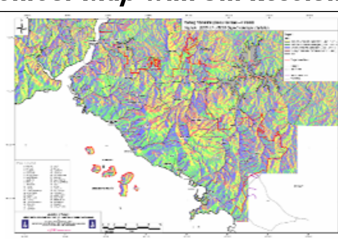
***Contour Map with 1m Resolution***



***Contour Map with 5m Resolution***

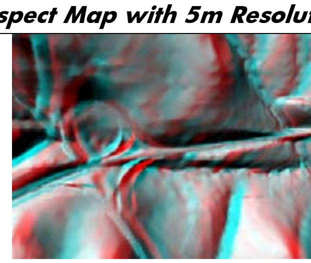


***Aspect Map with 1m Resolution***



***Aspect Map with 5m Resolution***

***Stereo-Image Map with 1m Resolution***



***Stereo-Image Map with 5m Resolution***

**Figure 3.2 3D Topographical Data Sets**

### 3.3 Geology

Geology maps in 1/2000 scale that will constitute a base for settlement convenience and microzonation studies that are planned to be performed in project site are initially produced.

At the beginning phase of the studies, pervious studies about the region that includes project site are compiled and analyzed. These studies are explained in ‘‘Initial Studies’’ section of the report entitled ‘‘Istanbul East Section Geology which is in between Kadıköy-Üsküdar Districts and Kocaeli Province Border’’. References frequently consulted during this study are Haas(1968), Kaya(1971;1973), Önalan(1982;1988), Gedik and diğ.(2005) and Özgül(2005). In planning, application and evaluation phases of boring studies, researches themed ‘‘Geology of Istanbul’’ conducted by project supervisor Dr. Necdet Özgül with the support of TÜBİTAK are substantially benefited. Stratigraphy and structural data and 1/25.000 scaled geology map provided by aforementioned research and not published yet are the basic data source for this project’s detailed geology, geophysics and boring studies.

Most of the project site’s being covered by settlement structures, artificial filling, talus etc. like current accumulations and accordingly lack of geological data stemming from insufficient surfacing (mostra) is tried to be eliminated by benefiting as far as possible from frequent diggings made in the region that are temporarily and shortly open such as itinerary, building pit.

In order to provide supportive data that will aid the solutions of geological problems encountered while making of 1/2000 scaled geology maps that will consititute a base for project studies and reveal project site’s general geological features, structural and stratigraphic purpose borings are planne and performed in required cases. In the specification of such kind of borings’ frequency and depth, geological problems whose solutions are aimed at leads the way.

Boring, geology and geophysic studies provisioned to be made in forbidden areas such as Tuzla Infantry School, Naval Academy, General Nurettin Baransel Barracks, Sabiha Gökçen Airport field and areas belonging to IBB Park and Garden Directorship are all performed by receiving permission from relevean authorities.

Security lines of approximately 200m width are formed in Oil and natural gas pipeline routes that are provided by BOTAŞ General Directorship and borings studies are made out of this line.

#### 3.3.1 Stratigraphy

Project site includes many rock-stratigraphy umits that are formed in a wide time interval starting from Early Paleozoic up to Now. (Chart 3.1; Figure 3.3). In this section, rockstratigraphy units surfaced on study field are explained with an order from older to younger.

**1) Polonezköy Group**

Sand stone, pebble stone, loamy stone and clay stone accumulations forming oldest rock units surfaced around Istanbul and gravitate in terrestrial (stream, lake, logoon) environment are analized in this study under the name of Polonezköy Group inspired by Polonezköy where surfacings cover wide areas. Polonezköy Group includes Kocatöngel Formation and Kurtköy Formation from older to younger.(Figure 3.4)

#### a) Kocatöngel Formation

It is mainly formed by laminated loamy stone – clay stone, and includes fine grained sandstone interlevels whose thickness is up to 1 m from place to place. Its fresh colour is greenish; weathering colour is grizzly, while it is fine-medium layered, cross and parallel laminated. Formation’s lower contact does not surface on study field and it is undertaken by Kurtköy Formation’s Bakacak Member compatibly.

Out of project site, it displays more than 2.000 m thickness in Yeniçiftlik valley (South of Mahmutşevketpaşa village) where most of the formation is surfaced. Kocatöngel Formation probably should be Early Ordovician aged since it partakes under Early Ordovician aged Kurtköy Formation transitively.

Millimetric sized, varved structure formed by laminas which displays crackled or wrinkled color alteration, reflects shallow, low energy environment conditions when glacial climate is effective. No findings of marine fossil on surfacings in formation research area make us think that Lake Environment conditions between deltas were dominant.

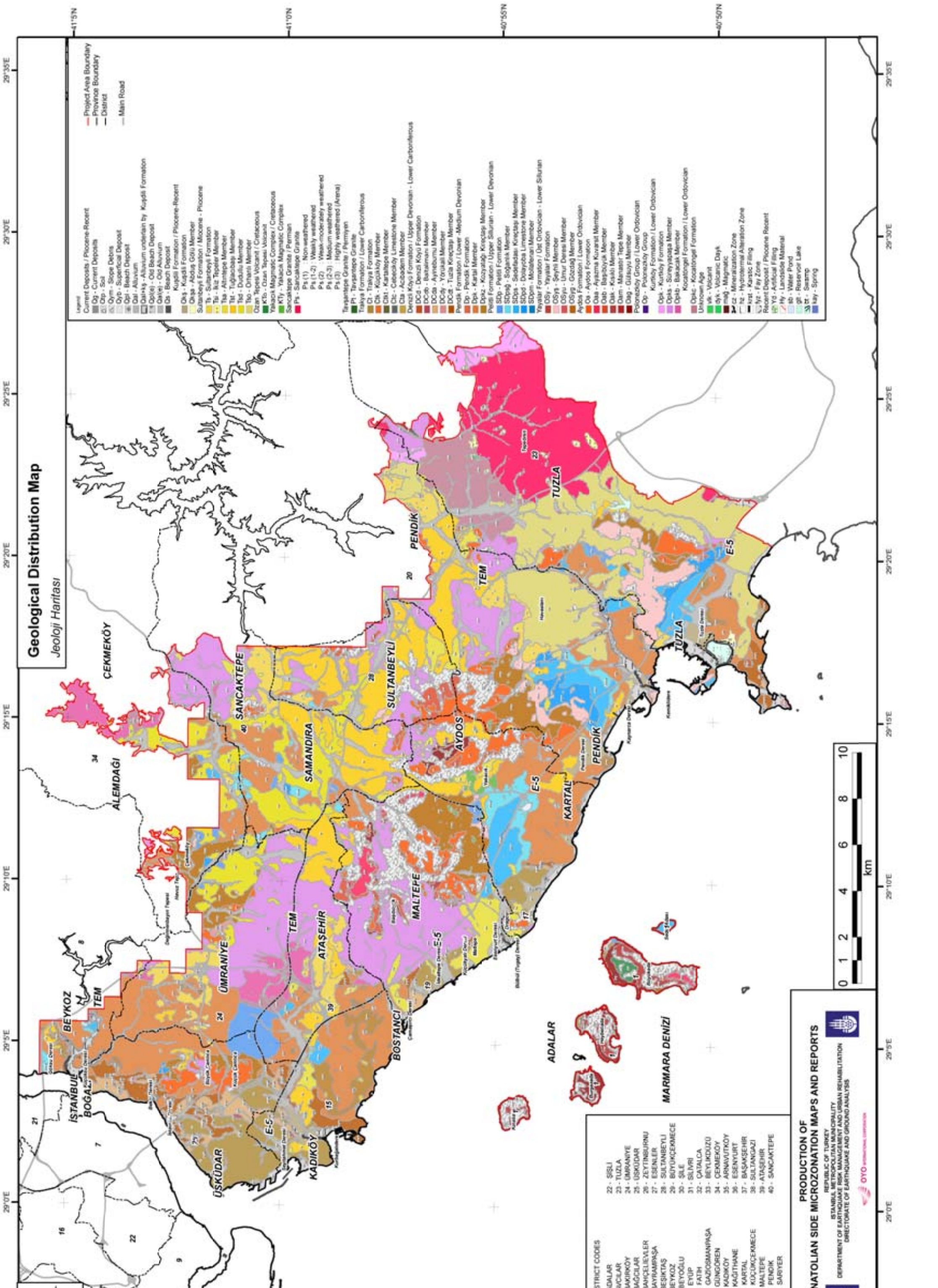



**Figure 3.3 Study Area Geology Map**

**Chart 3.1 Stratigraphy Units of Project Site**

| symbol | Formation | Member | Age |
|---|---|---|---|
| Qyb | Yüzlek birikintiler | Ayrılmamış | Kuvaterner |
| Qym | | Yamaç molozu | Kuvaterner |
| Qhy | | Heyelan gereci | Kuvaterner |
| Qkm | | Alüvyon | Kuvaterner |
| Qal | | Seki birikintisi | Kuvaterner |
| Qs | | Plaj birikintisi | Kuvaterner |
| Qkş | Kuşdili Formasyonu | Ayrılmamış | Kuvaterner |
| Qkşa | | Abduş Gölü Üyesi | Kuvaterner |
| Ts | Sultanbeyli Formasyonu | Ayrılmamış | Üst Miyosen-Pliyosen |
| Tsi | | İkiz Tepeler Üyesi | Üst Miyosen-Pliyosen |
| Tsa | | Altıntepe Üyesi | Üst Miyosen-Pliyosen |
| Tst | | Tuğlacıbaşı Üyesi | Üst Miyosen-Pliyosen |
| Tsd | | DudulluÜyesi | Üst Miyosen-Pliyosen |
| Tso | | Orhanlı Üyesi | Üst Miyosen-Pliyosen |
| Kh | Hereke Çakıltaşı | | Üst Kretase |
| Ko | Ozan Tepesi Volkaniti | | Üst Kretase |
| Ky | Yakacık Volkaniti | | Üst Kretase |
| TRgd | Demirciler Formasyonu | | Alt Triyas |
| Ps | Sancaktepe Graniti | | Permiyen |
| Pt | Tavşantepe Graniti | | Permiyen |
| Ct | Trakya Formasyonu | Ayrılmamış | Alt Karbonifer |
| Ctk | | Kartaltepe Üyesi; | Alt Karbonifer |
| Ctc | | Cebeciköy Kireçtaşı Üyesi | Alt Karbonifer |
| Cta | | Acıbadem Üyesi | Alt Karbonifer |
| CTk | | Küçükköy Üyesi | Alt Karbonifer |
| DCd | Denizli Köyü Formasyonu | Ayrılmamış | Alt Karbonifer-Orta Devoniyen |
| DCdb | | Baltalimanı Üyesi | Alt Karbonifer |
| DCda | | Ayineburnu Üyesi; | Alt Karbonifer-Üst Devoniyen |
| DCdy | | Yörükali Üyesi | Orta-Üst Devoniyen |
| DCdt | | Tuzla Üyesi | Orta-Üst Devoniyen |
| Dp | Pendik Formasyonu | Ayrılmamış | Alt-Orta Devoniyen |
| Dpkz | | Kozyatağı Üyesi | Alt-Orta Devoniyen |
| Dpkk | | Kartal Üyesi | Alt-Orta Devoniyen |
| SDp | Pelitli Formasyonu | Ayrılmamış | Üst Silüriyen-Alt Devoniyen |
| SDpsğ | | Soğanlık Üyesi | Üst Silüriyen-Alt Devoniyen |
| SDps | | Sedefadası Üyesi | Üst Silüriyen-Alt Devoniyen |
| SDpd | | Dolayoba Kireçtaşı Üyesi | Üst Silüriyen-Alt Devoniyen |
| SDpm | | Mollafenari Üyesi | Üst Silüriyen-Alt Devoniyen |
| OSy | Yayalar Formasyonu | Ayrılmamış | Üst Ordovisiyen-Alt Silüriyen |
| OSyş | | Şeyhli Üyesi | Üst Ordovisiyen-Alt Silüriyen |
| OSyg | | Gözdağ Üyesi | Üst Ordovisiyen-Alt Silüriyen |
| OSyu | | Umur Deresi Üyesi | Üst Ordovisiyen-Alt Silüriyen |
| Oa | Aydos Formasyonu | Ayrılmamış | Alt Ordovisiyen |
| Oaa | | Ayazma Kuvarsit Üyesi | Alt Ordovisiyen |
| Oak | | Kısıklı Üyesi | Alt Ordovisiyen |
| Oab | | Başıbüyük Üyesi | Alt Ordovisiyen |
| Oam | | Manastır TepeÜyesi | Alt Ordovisiyen |
| Oag | | Gülsuyu Üyesi ) | Alt Ordovisiyen |
| Opk | Kurtköy Formasyonu | Ayrılmamış | Alt Ordovisiyen |
| Opks | | Süreyyapaşa Üyesi, | Alt Ordovisiyen |
| Opkb | | Bakacak Üyesi | Alt Ordovisiyen |
| Opkc | Kocatöngel Formasyonu | Ayrılmamış | Alt Ordovisiyen |

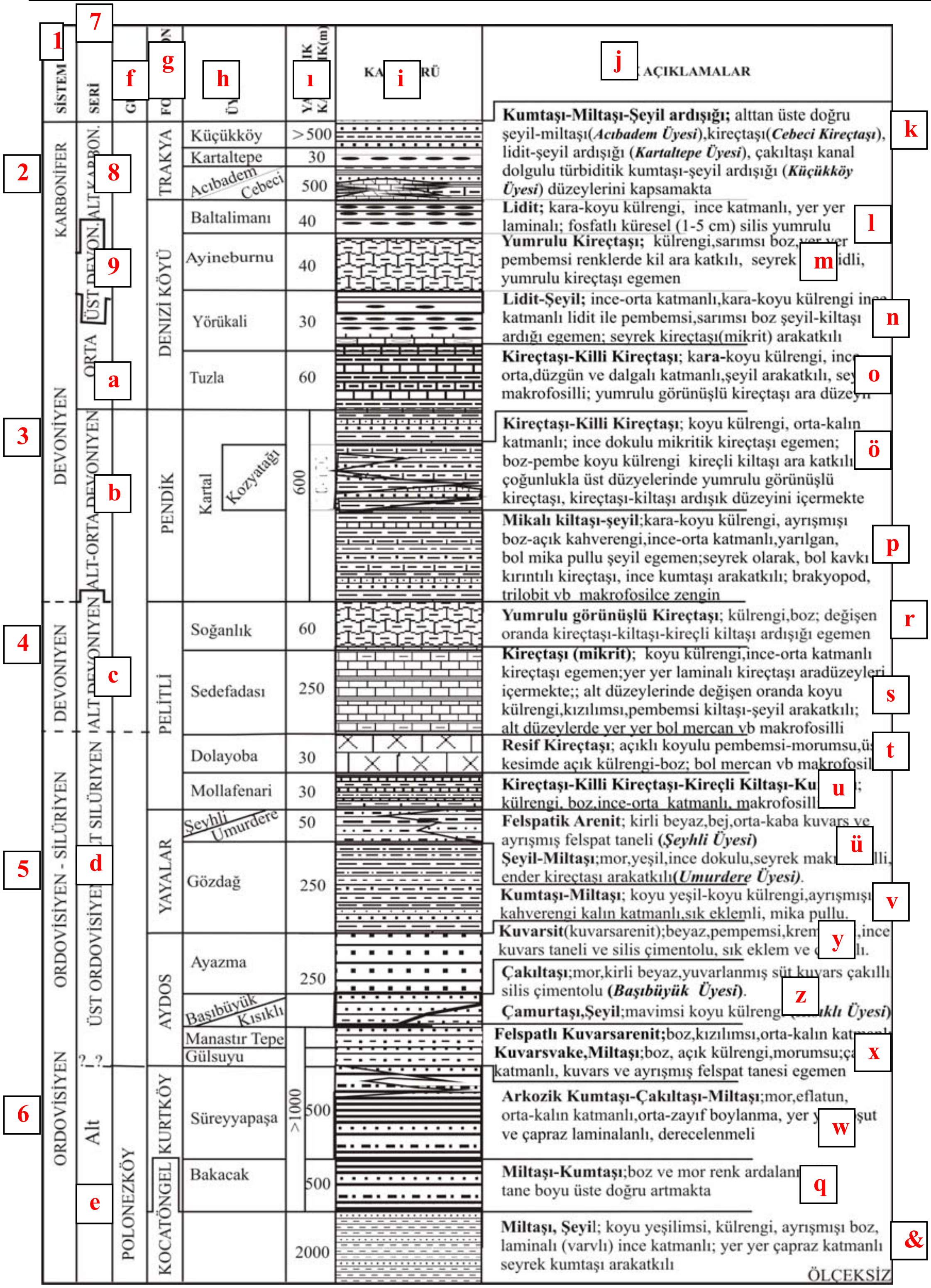



**Figure 3.4 Istanbul province and close vicinity generalized vertical section**

**1: SYSTEM**

**2: CARBONİFEROUS**

**3: DEVONİAN**

**4: DEVONİAN**

**5: ORDOVICIAN-SILURIAN**

**6: ORDOVICIAN**

**7: SERIES**

**8: LOWER CARBONİFEROUS**

**9: UPPER DEVONİAN**

**a: MIDDLE**

**b: LOWER-MIDDLE DEVONİAN**

**c: LOWER DEVONİAN**

**d: UPPER ORDOVICIAN-LOWER SILURIAN**

**e: LOWER**

**f: GROUP**

**g: FORMATION**

**h: MEMBER**

**ı: THICKNESS**

**i: LITHOLOGY**

**j: EXPLANATIONS**

**k: Sandstone-Milestone-Shale series;** from bottom to top shale-milestone (**Acıbadem Member**), limestone (**Cebeci limestone**), Lyddite-Shale series (**Kartaltepe Member**), turbiditic sandstone-shale series with cannel-filled gravel (**Küçükköy Member**)

**l: Lyddite;** black-dark ash-colored, thin layered, laminated in patches; phosphatic spherical (1-5 cm) silica nodules.

**m: Nodular limestone**; mainly ash-colored, yellowish grizzly, pinky clay interfingered, nodular limestone with rare crinoids

**n: Lyddite-Shale;** mainly, thin-mediate layered, black-dark ash-colored, thin layered lyddite and pinky yellowish grizzly shale-clay series; rare limestone (micrite) interfingered

**o: Limestone-Clayey limestone;** black-dark ash-colored, thin-mediate, flat and undulating layered, shale interfingered, rare macrofossiliferous; nodular looking limestone interleveled.

**ö: Limestone-Clayey limestone;** mainly, dark ash-colored, mediate-thick layered; fine textured micritic limestone; grizzly-pink dark ash-colored calcic claystone interfingered; nodular looking limestone at upper levels, limestone-claystone intercalations.

**p: Micaceous Claystone-shale;** mainly**,** black-dark ash-colored, weathered grizzly-light browned, thin-mediate layered, flakable, shale with rich mica lamellas; rarely rich shell fragmental limestone, thin sandstone interfingered, rich in macrofossils such as brachiopod, trilobite etc.

**r: Nodular looking limestone;** ash-coloured, grizzly; limestone-claystone-calcic claystone series in diffent ratios.

**s: Limestone (micrite);** mainly dark ash-colored, thin-mediate layered limestone; rare laminated limestone interlevels; at lower levels dark- ash-colored, crimson, pinky claystone-shale interfingered in different ratios, rich coral macrofossils at lower levels rarely.

**t: Reef limestone;** light-dark pinky-purplish, at high levels light ash-colored-grizzly; rich coral macrofossiliferous.

**u: Limestone-clayey limestone-calcic claystone-sandstone;** ash-colored, grizzly, thin-mediate layered, macrofossiliferous.

**ü: Feldspathic arenite;** oyster white, beige, mediate-thick quartz and feldspath grained (**Şeyhli Member**).

**Shale-Milestone**; purple, green, fine textured, rare macrofossiliferous, rare limestone interfingered (**Umurdere Member**).

**v: Sandstone-Milestone;** dark green-dark ash-colored, weathered, brown thick layered, close-jointed, mica scaled.

**y: Quartzite (Quartz arenite);** white, pinky, beige, thin quartz grained and silica cemented, close jointed and fissured

**z: Gravelstone;** purple, oyster white, rounded smoky quartz gravels, silica cemented (**Başıbüyük Member**)

**Mudstone, shale**; bluish, dark ash-colored (Kısıklı Member)

**x: Feldspathic quartzarenite;** grizzly, crimson, mediate-thick layered

**Quartz vake, Milestone;** grizzly, light ash-colored, purplish; cross layered, quartz and weathered feldspath grained

**w: Arkosic sandstone-Gravelstone-Milestone;** purple, violet, mediate-thick layered, mediate-slight sorting, cross and parallel laminated in patches, gradational

**q: Milestone-Sandstone;** grizzly and purple coloured intercalations, grain-size increases to the upper levels

**&: Milestone, shale;** dark greenish, ash-colored, weathered, grizzly laminated (varved), thin layered; cross layered in patches, rare sandstone interfingered

### b) Kurtköy Formation

Kurtkoy Formation consists mainly of crackled or wrinkled alteration purple-violet color clay, alluvion, sand and gravel sized material including arcose composition clastic rocks. It is divided into two groups one of which is Bakacak Member at the bottom and the other is Süreyyapaşa Member on the top (Figure 3.4).

Bakacak Member that is formed by sandstone intercalated, fine laminated clay stone-loamy stone is in approximately 500m thickness on north of research area on surfacing of Yeniçiftlik brook Özgül (2005). Süreyyepaşa Member forms top part of the Formation. Coarse sand stone that is claystone-loamy stone intercalated and including various sizes of pebble stone lenses and interlevels are dominant.

Kurtköy Formation undertakes Kocatöngel Formation compatibly and transitively, and is undertaken by Aydos Formation compatibly. The Lower Ordovician aged formation’s total thickness is thought to be more than 1000m.

Formation reflects alluvial fan environment conditions in which oxidation conditions effective and which are fed by a source of tectonic activity.

**2) Aydos Formation**

Aydos Formation is mainly formed by quartzites (quartz areanites). Quartzite is oyster white, pinky, cream, purple, weathered ones are crimson-brown, light brown, medium-thick-very thick, mostly uncertain layered, laminated and graded from place to place. Intercalations that are 5-10 cm thick from place to place, anisochromatic color clayed and alluvial shale, clayed sand stone (quartzwake) are seen.

Aydos Formation is divided into 5 members such as Gülsuyu Member, Manastır Hill Member, Başıbüyük Member, Kısıklı Member and Ayazma Quartzite Member.

Gülsuyu Member that forms the lowermost part of Aydos Formations is mainly consists of cross layered, feldspathed sand stone- loamy stone. Unit thickness that changes from place to place reaches up to 200 meters in Kınalıada. Manastır Hill member consists of feldspathed quartzites and its surfacing in Kınalıada is approximately 50m thick. Başıbüyük Member that consists of purple , cream, cross and parallel lamina rounded quartz gravelled and silica cemented pebble stone and coarse grained sandstone is average 40m thick. Ayazma Quartzite Member is totally formed by quartz aranites, and it is one of the most widespread and examinant levels of Aydos Formation. It is pinky cream, oyster white, fine sand size quartz grained and silica cemented. Aydos Mountain is approximately 50m thick. Aydos Formation’s lower part cut, color alterated green, dark ash gray, purplish from place to place weathered parts are brown-grizzly, pyrite crystalline, mud stone- loamy stone level in some of the borings that are performed on at the skirts of Big and Small Çamlıca skirts especially around Kısıklı district are called as Kısıklı member in this study.

All these members exhibit lateral and vertical interdigitation, and reflect shallow shore sea conditions that include beach, sand spit and loggon environment.

Aydos Formation undertakes Kurtköy formation with agonic noncompatibility, and is undertaken by Yayalar Formation compatibly and transitively. Unit thickness changes frequently in lateral direction with approximately 200 meter of thickness in Aydos Mountain and 30-40 meters in Dudullu’s west and north ridges. It should be at Upper Ordovician-Lower Silurian age since it is undertaken by Upper Ordovician- Lower Silurian aged Yayalar Formation.

### 3) Yayalar Formation

The formation mainly formed by micaceous feldspathed sand stones is preferred to be analysed (Özgül,2005) under the name ''Yayalar Formation'' used by Haas (1968) Sand stone- loamy stone with various grain sizes are Yaylar Formations dominant rock type. Formation is divided into 3 members such as Gozdağ Member, Umurdere Member and Şeyhli Member (Figure 3.4).

Gözdağ member forms essenial part of Yayalar Formation. It is green, livid, light brown when weathered, grizzly medium layered, fine layered and parallel lamina from place to place. Especially in weathering zones that develops along the tectonic lines for example along the thrust zones that surround Big and Small Kaynarca hills, mica and feldspath content exhibits extreme weathering and rock turns into clay which is fine quartz material yellowish, grizzly, redish light blueish gray. Reddish burgundy shale level that takes place on Gozdağ Member is named as Umurdere Member by Haas (1968). Şeyhli Member consists of felspathed quartzites that are seen on top level of Yaylar formation in forms of big lenses from place to place.

Yayalar Formation theat represents Upper Ordovician-Lower Silurian gap undertakes Aydos Formation compatibly and penetratively, while it is undertaken by Pelitli Formation compatibly. It has been detected by utilization of boring data performed on Formation that the formation is 280-300m thick.

### 4) Pelitli Formation

Pelitli Formation whose essential part is formed by limestone is pink and gray clay intercalated especially in bottom levels, and it covers nodular limestone level on upper section. Formation is identified by dividing into several different named formations by various researchers. Özgül, (2005) preffered to name all of the hoard that display no specific cutting in gravitation and mostly formed by shelf type carbonates as on single formation name, while Haas (1968) preffered to use Pelitli Formation name considering that some part of the aforementioned limestone is (Pelitli schichten).

Pelitli formation consists of chalky shale-sandstone-claey limestone-lime stone sequence, abundant macrofossiled reef limestone, medium-fine layered, lamina biomicrite and fine shale intercalated nodular limestone levels from bottom to the top. Starting from the bottom the formation is divided in to 4 members such as 1)Mollafenari Member 2)Dolayoba Limestone Member, 3) Sedefadası Member and 4)Soğanlık Member.

**Mollafenari Member:** It forms the lowermost level of Pelitli Formation. Mainly consists of limestone-clayed, sandy limestone-chalky clay stone, sandstone sequence.

**Dolayoba Limestone Member:** It forms one of the examinant levels of Pelitli limestone partaking at lowermost, and including abundant corraline, color alterative pinky, gray reef limestones at the top.

**Sedefadası Limestone Member:** It is represented by Dolayoba Limestone Member's reef limestone layer over, black-dark gray, fine-medium layered, lamina limestone-shale from place to place inter levels including carbonate hoard.

**Soğanlık Limestone Member:** Soğanlık Limestone Member that forms the top of Pelitli Limestone consists of nodular looking, fine-medium layered, limestone-clayed limestone and 1-2 cm thick shale sequence.

Pelitli Formations thickness changes from place to place depending on shallow and unstable gravitation conditions. Total thickness of the formation's hoard in Kartal quarry is calculated as 370m by benefiting from boring data. Pelitli Formation represents Early Silurian – Early Devonian gap.

**5) Pendik Formation**

Pendik Formation mainly consists of clay-alluvion-fine sand size material, micaceous shales and in specific sections especially the upper levels it is limestone intercalated. Includes Kartal and Kozyatağı members. (Figure 3.4).

Shales that cover wide areas in Istanbul's Anatolian side Kartal Member are distinctive for abundant macrofossil content. It forms the rock type which is black-dark gray when fresh, dark greenish from place to place, grizzly-light brown when weathered, fine- medium layered, cracky, abundant micaceous shales dominant. Infrequently covers mica sandstone and fossil clastic limestone inter levels of various thicknesses (5-10 cm). It includes the level known as Kozyatağı member which is formed by different levels of calcic limestone – clayey limestone – limestone on upper half of Pendik Formation. Fine-medium layered, dark gray limestone froms the dominant rock type of the member. Clay – lime level changes from place to place, so constant transitions between calcic claysone- clayey limestones are obeserved.

Pendik Formation undertakes Pelili Limestone compatibly and it is undertaken by Delizli Village Formation compatibly too. Thickness calculated on he map is approximately 600 meter in the south section of Korucu village of the formation, it is at Lower and Medium Devonian age.

**6) Denizli Village Formation**

Hoard that is mainly formed by shale intercalated clayey limestone, limestone, lyddite and nodular limestone is analysed under various names such as Denizli Formation (Haas,1968), Büyükada Formation (Kaya,1973), Tuzla Formation (Önalan,1981) by various researchers. Özgül (2005) used the name Denizliköy Formation (Haas,1968) considering priority rule.

Formation is analysed by dividing into 4 members such as **Tuzla Member"**, **"Yürükali Member"**, **"Ayineburnu Member"** ve **"Baltalimanı Member"** from bottom to the top.(Figure 3.4)

Tuzla Member mainly consists of black-dark gray, fine-medium layered, fine shale intercalated, infrequent fossil clastic, and nodular looking micritic limestones. Thickness of the member is approximately 60m. Yörükali Member that is 30m thick consists of fine shale intercalated lyddites and undertakes Tuzla member's micritic limestone layers compatibly. Small nodular limestone-clayey limestone unit raking place on Denizli Village Formations top level is named as Ayineburnu Member by Kaya (1973) and is approxiamtely 40 m thick. Baltalimanı Member mainly consists of lyddites, shale and silica shale intercalated rising through upper levels and exhibits 40m thickness.

Denizli Village Formation undertakes Kartal Formation compatibly and is undertaken by Thrace Formation compatibly. The formation which is about 170 m thick gravitates during Middle Devonian – Early Carboniferaus period.

**7) Thrace Formation**

Thrace Formation consists mainly of sand stone, loamy stone and shale sequence. It includes pebble stoen from place to place and at he lower half there are limestone intercalations and lenses. In this analysis Thrace Formation is divided into four members such as 1) Acıbadem Member 2) Cebeciköy Member 3) Kartaltepe Member and 4) Küçükköy Member (Figure 3.4).

Acıbadem Member, forming the lowermost unit of Thrace Formation, consiss mainly of clayey, silty shales and is infrequently cilstone and fine sand size grained sand stone intercalated. It exhibits approximately 200m thickness in its surfacing on the south of Gebze district. Black-dark gray ran as quarries from old times around Cebeciköy, medium-thick-very thick layered, abundant organic content limestones are named as Cebeciköy Limestone Member. In Cebeciköy quarries where unit is most thick, specific thickness is not known since base is not revealed. Kartaltepe Member which mainly consists of lyddite intercalated shales takes palce in lower section of the formation. It is represented by yellowish-grizzly shale-clay stones on limestone level in Cebeciköy quarries. Its thickness is approximately 30m. It is formed by abundant micaceous turbitic coarse sand stone-shale sequence in filiş fasies of Küçükkköy Member that forms formation's upper section. Member's thickness is thought to be more than 500m.

Thrace Formation undertakes Denizli Village Formation's Balalimanı member compatibly. Surfacings that do no cover the entire hoard are at most 500m thickness in study field. There are fossils found that display Early Carboniferaus age in limestone and shales of Thrace Formation's lower levels.

**8) Sultanbeyli Formation**

Post tectonic sediments that cover wide areas in especially east section of the project site are grouped under the name of Sultanbeyli Formation in this study. Sultanbeyli Formation consists of unattached sand, gravel, clay, and clastic material block from place to place that are lateral and vertical transitive with each other. Formation's hoards in project site are analysed under the names of Orhanlı Member, Dudullu Member, Tuğlacıbaşı Member and İkiztepeler Member according to dominant lithology features.

Most part of the Orhanlı Member consists of clay-alluvion-fine sand sized materials. Blueish gray when fresh, grizzly when weathered, light brown clayey-alluvial material forms the dominant rock type. It involves sand-gravel and block size unattached coarse material lense and intercalations in some regions especially gravitation environment's close to shore sections. Various ratios of calcic congressioned clay-alluvion size fine material are dominant in gravitation environment's far from shore sections almost all of the hoards.

Orhanlı Member's unit thickness differs between 0-150m depending on inconsistent base topography. Dudullu Member consists of units almost all of them are clay, light brown, cream, soft, high plasticity, low silty uniform clay. It is fine sand intercalated infrequently. Sultanbeyli formation's sand, gravel accumulations are named as Tuğlacıbaşı Member in this study. Oyster yellow, reddish brown, sand-alluvion paste and half rounded-half cornered, poorly sorted, quartzite, quartz, flint stone and blacky lyddite origin sand, gravel and infrequent blocky material are dominant in most of the surfacings, and it includes arcose, sandstone and volcanite material in lesser proportion. Sand-gravel ratio differs fom place to place. Cross lamination, lensing and wedging stuctures are usual. Member's thickness changes between 3-5m and 30-40 depending on base topography. On the N-S directional ridges that are formed by Paleozoic aged rock units between Bostancı-Küçükyalı-Maltepe-Cevizli, coarse blocky gravel-coarse sand accumulations protected in conditon of thin-film are named as Altıntepe Member. Altıntepe Member's thickness changes frequently from place o place with an average of 20-30m. On the ridges where generally Sancaktepe Granite and from place to place Kocatöngel Formation surfaced areas the fine sand-gravel accumulations that take place on approximately 200m altitudes are named as İkiztepeler Member. Reddish, yellowish, grizzly, oyster white colored half comressed, fine-medium-coarse sand size is dominant. İkiztepeler Member that is protected by ridges where Sancaktepe Granite which turns into arena by weathering is widespread includes mostly derived from granite half rounded, medium sorted quartz and weathered feldspath grains. İkiztepeler Member's open to erosion surfacing's thickness in İkiztepeler location is 8-10m.

Sultantepe Formation undertakes Paleozoic and Mezosoic aged rock units with angular unconformity via its various members. It is undertaken by Kuşdili Formation and Current talus incompitibly. Formation's thickness differs from 20-30m and approximately 150 depending on base topography and proximity to source area.

Palinology purpose samples that are selected from boring cores are analysed by Prof. Dr Fında Akgün (DEÜ) and palinomorphs that represent Late Miocene- Pliocene are detected.

**9) Kuşdili Formation**

There are accumulations consisting of dark colored clay, alluvion, mud type fine material with different thicknesses of 20-30m and 70-80m in downstream sections of Istanbul's big streams opening to Marmara Sea and Bosphorus. In downstream section of Kurbağlıdere in Kadıköy district, the unit is named as ''Kuşdili Formation'' by Meriç and others (1991) who examined the boring data conducted on the meadow known as Kuşdili and covering such kind of accumulations.

Formation consists of black-dark blueish gray, dark green, generally organic content high, carbonated plant clastic estuary-logoon accumulations. Mainly includes clay, alluvion, sand size material, and grain sizes differ from place to place. It covers half rounded gravel and gravellite sand lense and intercalations infrequently. It is fine full of shells and fine attired marine lamellibranch, gastropod etc macrofossil full of shells. Clay and water content in high proportion makes it soft, consistent and high plasticitied. For these properties it exhibits liquidation risk high soil feature.

Abduş Lake Member consists of calcic congression silted clay and marn. It is generally formed in lagoon environments shore regions where Kuşdili Formation gravitates around Abduş Lake and Tuzla Dockyard. Member thickness is between 10-15m

Kuşdili Formation generally undertakes Paleozoic aged rock units with angular unconformity within project site, and its thickness differs from place to place. According to boring data, thickness decreases in stream valles opening to Marmara Sea and Bosphorus and when going insider upstream (spring) and from valley axis to valley edges. Kartal Member's shales that form base rock of 19.5m alluvium and 40.5m Kuşdili formation with a total of 63m depth are found in 1290371D-2 No. trench's 2 m altitudes of Göksu streams reaching sections to the shore.

In age determination with C14 on carbonated plant particles taken from 1270371D-1 no. bore hole's 55.5, 60.0 and 62.0 m and 1270372N-1 bore hole's 41.90m made in Küçüksu brook's reaching to Bosphorus plain within the scope of the project ages that corresponds to Holocene such as 9.380 ± 50 y, 11.050 ± 50 y and 11.100 ± 50 y and 8790 ± 50 y found. In Çengelköy

Bekar stream mouth on the other hand 7220 ± 50 y ve 7190 ± 50 y are found by the C14 method age determination on carbonated plant particles taken from 29.50 and 33.00 depths. Consequently Kuşdili Formation is understood to be at Holocene age.

**10) Current Talus**

Terrace talus of 2-3m thickness that includes half compressed, unsorted sand, gravel, alluvion, clay mixture alluvial material are observed in project site's north east sections for example in stream beds pouring out to Ömerli dam lake on Istanbul Park Racing Pist's west. Such type of shapes form productive areas for local greenhouse and farm agriculture. Generally shallow (3-5m thick) and narrow Alluvium accumulates in Göksu Küçüksu and Bekar brooks opening to Bosphorus and Kurbağlı, Çamaşırlık, Küçükyalı, Büyükyalı (Narlı), Tavşan, Kemikli and Umur brook valley bases opening to Marmara Sea in project site. Bases of these reaching to sea valleys are generally low inclined and they are low energied because of getting closer to today sea level, and since their stream strenght is low clayey, alluvial, sand-gravel accumulations are dominant. Alluvium accumulations generally involve rounded-half rounded, poorly-medium sorted, mostly quartzite, sand stone, limestone and volcanite origin clayey sand, alluvion and small sized gravel. Clay, alluvion ratio is generally high.

Small Beach talus develops in some stream mouths opening to Marmara Sea. Such type of accumulations whose base altitudes can go under 5-6 m from sea level take place generally in naural ridge edges that exend along the sea and so coastal currents and bays that can be protected from waves develop (Moda, Caddebostan beaches) Washed and sorted, coarse sand and rounded tiny gravels are dense. Some of the fine beach lines stay underartificial filling because of road expansion works.

Talus accumulations from place to place develop in skirts of high sloped mountain and hills that are formed by region's quartzite etc. resistive rocks, mostly in incline refraction areas. Such type of accumulations with 30-40m thickness from place to place are widespread on Aydos Mountain, Kayış Mountain, Big and Small Çamlıca hills' slope and skirts. It involves sand, gravel, block size cornered-half cornered, poorly sorted material and yellowish brown-crimson clayey alluvial paste. In some sections revealed by some base diggings in Yakacık district gravels are observed to display sequence and to intercalate with crimson colored clay-sand size fine clasts.

Especially in east and north above high slopes of Kınalıada, talus accumulations that reach 20-30m thickness which increases gradually down the incline and reaching up to 40-50 m altitudes starting from sea shore develop.

### 3.3.2 Magmatites

Sancaktepe Granite that covers wide areas on the east of the Project site, gabro that is related to this granitic magma and only cut by borings, microdiorite etc vein shores, andesitic and diabasic dykes and dasitic volcanites surfaced on Büyükada are main magmatites of the project site.

**1) Sancaktepe Granite**

Granites that cover an area with approximately 100km² width between Akfırat, Tepeören, Şekerpınar and Çayırova villages on the east of project site are analysed under the name of ''Sancaktepe Granite'' by Yılmaz (1977)

Sancaktepe Granite involves pink, oyster white, coarse crystalline, quartz, feldspath, biotite and opaque mineral. It is understood from the borings in granites at 20-30m depth that weathering is not superficial. According to the information obtained from water boring performing companies weathering continues more than several hundred meters depth depending on pneumatolytic weathering. In most of the granite surfacings, since with the effect of atmospheric conditions weathering progresses up to 10-15m deeps from the surface, rock gain half loose, easy to scatter physical properties, and so in the quarries opened in granite surfacings, filling material can be taken out with dipper in up to 10-15m deeps.

Sancaktepe Granite is only cut by Ordovican aged Kocatöngel and Kurtköy formations in the project site. However, Paleosoic precipitation that covers Ordovician-Early Carboniferaus displays continuity without significant interruption and this requires Granite Intrusion's younger than Early Carboniferaus. Moreover, close data such as 255±5my by Rb-Sr method and 254my by K-Ar method are found in age determinations made by Yılmaz (1977). Accordingly when stratigraphic relations and geochronologic data is evaluated together, Sancaktepe Granite's intrusion age is understood to be Permian.

**2) Tavşantepe Granite**

Tavşan hill on E5 (D100) highway within Pendik province borders and granite surfacing around it is known as Tavşantepe Granite. It turns into arena by advance weathering same as Sancaktepe Granite. It cuts Pelitli Limestone by its surfacing of Tavşantepe.

Tavşantepe Granite should at least be younger than Early Carboniferaus since it cuts Pelitli Formation. However, its intrusion's upper age limit is unknown. It can be of same age with Sancektepe though the possibility of its being younger as Çavuşbaşı Granite (Upper Cretaceous) is still a can be.

**3) Gabro**

Gabro type magmatites are cut in some of the borings in the area where Sancaktepe Granite is widespread on the east section of the Project site. It is observed in one hand sample's thin section taken from 540473 no. boring core (19.5m) that more than 90% of rock is green, coarse grained (1-2 mm), half euhedral horblend crystallines. Among hornblend crystallines plagioclase crystallines that are sericitizationed and subsituted partially by pumpellyte takes place.

**4) Yakacık Magmatite Complex**

Vein rock type magmatites and volcanites are surfaced in Yakacık-Uğur Mumcu district of Pendik province. Magmatites cut in the borings performed around this vicinity are analysed under the name ''Yakacık Magmatite Complex'' since they involve volcanites and intrusives which display differences in terms of mineral content and texture features. Some magmatite types encountered within the Complex are briefly described below.

**5) Ozan Hill Volcanite**

Dasitic volcanites that cover most of the Ozan hill which takes place on the north section of Büyükada are named after the hill in this project. Ozan Hill Volcanite that gathers oyster white, yellowish light brown, rust color, brindled, porous looking as a result of advanced decomposition lost its original texture and composition substantially in general. It involves plagioclase and infrequent quartz phenocrystallines that are sericited in a paste consisting of fine grained quartz, feldspath and sericite.

### 3.3.3 Structural Geology

Tectonic movements of various durations were effective at Early Carboniferaus-Neogene gap in Marmara region. Structural elements depending on these movements such as fold, fault, joint, etc. gives the region a complex structural feature.

**1) Faults**

Presence of great and small many faultlines that are E-W, N-S, NE-SW and NW-SE directional in section especially surfaced by Paleozoic-Lower Tertiary aged rock units in prject site attract attention

Besides faultlines distinctive with map sample during guide level etc linearities directly observed or contact regional faultlines which are kilometres long such as: Maltepe-Beykoz Faultline, Yakacık Faultline, Dragos Faultline, Çamlıca Overlay, Umraniye Faultline, kartal Faultline, Gölcük Hill Faultline, Büyükada Faultline develelop, an they are observed and mapped. As aforementioned these faultlines are not active, they are covered by Late Miocene-Pliocene aged Sultanbeyli Formation instead. Structural geology map produced for project site is given in Figure 3.5.

**2) Layer and Joints**

Layer and joint plain locations measured in study field are tried to be evaluated by using Schmidt equal-area network with histograms. This evaluation is conducted on Kurtköy, Aydos, Yayalar, Pelitli, Kartal, Denizliköy, Thrace Formations; furthermore an evaluation is also made for all of the Paleozoic union together in study field.

**3) Folds**

Surfacings being constricted and being covered by inadequate and post-tectonic sediment and crop talus makes regular layer measurements impossible to be performed. It is observed that compressed folds that come out in base diggings and shore edges developed. Frequent and asymmetrical folds develop in shale intercalated fine layered limestones such as Denizli Village, Pelitli Formation Soğanlık member and rock units whose clay content is high such as Kartal member, Thrace Formation Acıbadem Member. Most of the mezoscopic folds that can be observed from place to place in such type of units are approximately N-S axial and asymmetrical to E or W.

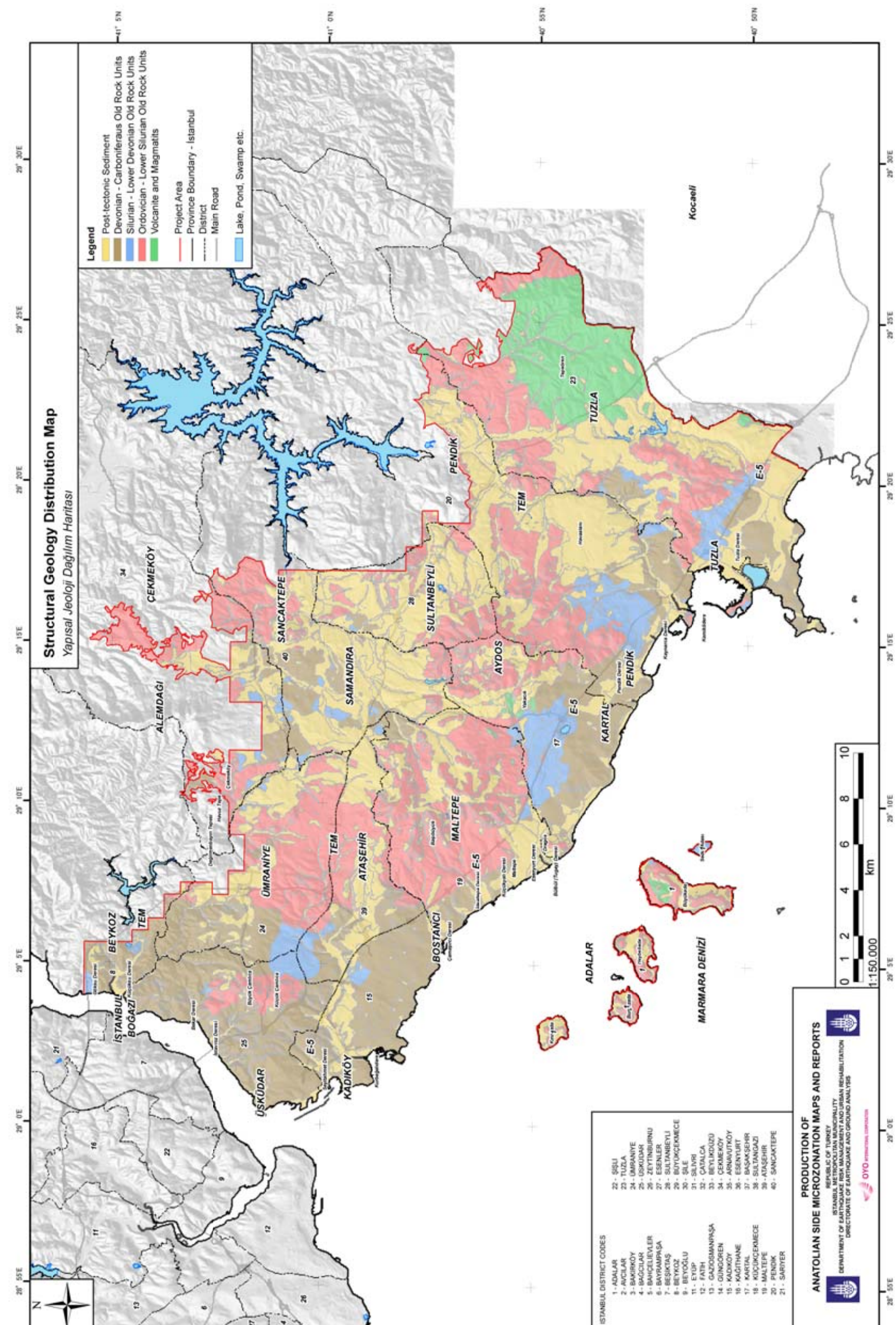



**Figure 3.5 Structural Geology Map**

### 3.3.4 Thoughts about Region's Geological Development

In the study field that is surfaced by Paleosoic and Plio-quarterner aged rock units, Lower Ordovician aged terrestrial sediments (Kocatöngel Formation and Kurtköy Formation are the mostly surfaced rock units. The region which was in rock form at Early Ordovician is covered by a stable sea that starts with a trangession represented by Ordovician aged Aydos Formation's quarzvake and quarzaranites and gradually deepens from Silurian to Devonian. Yayalar Formation(Upper Ordovician-Lower Silurian) represented by loamy stone- sandstone, Pelitli Formation(Upper Silurian-Lower Devonian) that reflects shelf type carbonate sediment, Pendik Formation( Lower-Medium Devonian) that represents low energied shelf environment and covers abundant macrofossiled, infrequent limestone intercalated micaceous shales, and Denizli Köyü Formation (Upper Devonian + Lower Carboniferaus) that represents open shelf-slope environment and where nodular limestones are dense all gravitate during this process from older to younger. Lower Carboniferaus aged Black silica (lyddite) sediments (Baltalimanı Member) that partakes in Denizli Village Formation as interlevels and can be observed as a guide level on the top section make us think a volcanic activity that leads to a dense silica bringing near mentioned marine estuary. Estuary that exhibits tectonic stability until the beginning of Carboniferaus from Ordovician turns into a ustable environment character that is represented by filish type sandstone-shale sequence (Thrace Formation) in Lower Carboniferaus where turbiditic currents are effective. In the Carboniferaus – Permian gap depending on tectonic movements, magmatic intrusions represented by Sancaktepe Granite (Permian) develop and region turns back into land form by getting out of water.

Elevations' such as Çamlıca hills formed by Aydos Formation, Aydos Mountain, Kayışdağı showing extention close to N-E direction, Çamlıca Overlay's being N-S directional and tend to E, N-S directional folds on the west of this overlay's being advanced, and N-s axis directional assymetrical mezoscopic folds being observed frequently indicate that tectonic movements which affect Early Corboniferaus rocks most probably in Carboniferaus-Permian gap and leading to E-W directional significant compressions are effective in the project site.

Around Şile and Gebze out of project site two big trangressions that affects the all of the region in Permian and Late Cretaceous are observed.

Direct data information about the age of microdioritic, andesitic vein rocks and volcanites which both give surfacing in the project site and revealed requently in diggings are not yet provided. Nevertheless, Çavuşbaşı Granite (Bürküt, 1966; Öztunalı and Satır, 1975) that is specified as Cretaceous (Santonian-Danian) by geochronologic age determination studies and represent an asidic magmatizm covers wide areas on north of project site (N of Çekmeköy). Considering Sarıyer Group's Upper Cretacerous aged volcanism, effective in Black Sea shore, the magmatizm in project site age must be Upper Cretacerous. Compressive movements that affect most part of the Anatolia in Eocene lead to dense foldings and faultings in Marmara basin that covers Istanbul region as well. Sarıyer-Şile Faultline that leads to Paleozoic and Mezosoic aged rock units overlay to Upper Cretaceraus-Early Eocene aged hoards and cover the region in NNW-SSE direction is thought to be developed depending on these movements.

In Şile, region exposed to a new trangression in Middle Eocene (Lutetian). In Middle- Late Oligocene, depending on tectonic movements that affect Thrace basin totally, region rises again and enters into a blackening and peneplaination duration and stream-lake-logoon accumulations that represent especially Late Oligocene-early Miocene gap cover wide araes. Depending on Oligocene movements that lead to north-south directional compression NW-SE and NE-SW axis directional shear fault and joint systems are densely developed. Weakness zones developing along these shear cracks detect Istanbul and Çanakkale straits and regions gib stream valleys and Golden Horn's morphological development and zigzagged direcitonal drainage sample in convenience with NW-SE and NE-SW directions develop. These fault and shear cracks that are reflected nicely by the weakness zones they form are not detected by the field data to be active today, in contrast they are observed to be found covered by Upper Miocene-Pliocene aged Sultanbeyli Formation. In downstream section of Kurbağlıdere, Kuşdili Formation's being more shallow with 40-45m depth indicates that the sea level between Istanbul's Anatolian Side and Adalar was shallow it is today.

### 3.3.5 Conclusions

Conclusions provided by the study which is made to analyse Project site's geological features starting from Istanbul Anatolian Side east shore between Kadıköy and Üsküdar districts and Kocaeli province border, including south section and to prepare 1/2000 scale geology map are given in a nutshell below

- As a result of this study 1/2000 scaled geology map of a 509.62 km² wide area including a total of 465 topography sheets that are 1/2000 scaled are made.

- In mostly covered by dense settlement structures project site, surfacings being constricted, inadequate and covered by post-tectonic sediment and curret talus, some important tectonic discontinuities primary features being coeval or shadowed by a more young magmatizm etc. reasons, analyses can be made only in limited areas and correlations between surfacings are sometimes open to comment. However, these problems are tried to be eliminated by obtaining underground data with shallow and deep borings condcuted on many problem solving places in projec site and by examining base diggings that becomes denser recently some of which are big and deep.

- All of the diggings made during surfacings that take place in project site and geology studies are mapped considering actual sizes of them and mostra map is prepared.

- In geological map receiving studies, the method of rock-stratigraphy units mapping in formation and member phase is pursued. Former researches are scanned for this and data related to rockstratigraphy units' names and stratigraphy relations that surfaced around province area and its vicinity are examined and rock-stratigraphy classification is made alse considering Stratigraphy Naming Rules.

- In stratigraphy purposed deep borings it is determined that Pelitli Formation is 370m with its surfacing thickness on the surface, Yayalar Formation's Gözdağ Member is 230m- with Şeyhli Member that has very variable thickness- is 280-300m thick.

- 1/5.000 scaled Structural Geology Map which includes study field's structural elements is prepared

- Rock type features of rocks, fault, joint, layering etc discontinuities and hoards revealed by surfacing and diggings are examined and displayed.

- Since structural elements that can only be displayed in borings because of dense structuring such as layering, joint, fault etc. are hard or impossible to be monitored in lateral direction, places that are key areas about region's structural features and can enlighten general tectonic style are selected.

- Near big faultline zones whose lateral continuity can be detected, it is understood that these faultlines are generally steep-very steep inclined by borings made to find faultline incline and faultlines linear directions

- Structural elements such as faultline, fold axis, layer, joint etc. that are observed in project site are studied by rulers and digitized. Layer and joint plane conditions measured in study field are tried to be evaluated by Schmidt equal-area network. This evaluation is done for Kurtköy, Aydos, Yayalar, Pelitli, Kartal, Denizliköy, Trakya Formations, and an additional evaluation is also performed for all Paleozoic hoards within project site. Layers and joints are discussed separately and as a result two different distribuiton frequency analyses are performed for each formation. Apart from these, for Pelitli Formation's Sedefadası Member only layer location analysis is made while for the surfacing seen clear on south section Aydos Formation's Büyükada both layer and joint location analyses are made.

- In areas where Miocene-Pliocene aged Sultanbeyli Formation's surfacings are present NE-SW and NW-SE directional conjugated faultlines are covered by this formation so they have no active faultline property.

- No active faultline presence is detected in Istanbul province border during these studies.

- Age determinations of samples that are compiled from boring cores and surfacings in Pelitli and Denizli Village Formations depending on conodont content are made and layer level ages belonging to Silurian and Devonian system are obtained.

- It is understood from both interpretations of base relief and palinologic age determination that Sultanbeyli Formation is Upper Miocene (?) Pliocene aged which covers wide areas on the east of project site and corresponds to the terrestrial sediments that are mapped under the names of Oligocene-Lower Miocene aged Meşetepe and Kayalıtepe in 1/50.000 scaled geology maps that are published by MTA Genarl Directorate.

- With borings aimed at revealing base relief of Sultanbeyli Formation that includes Upper Miocene (?)- Pliocene aged terrestrial sediments, this formation is proved to be gravitated on a high relief base. Considering the base relief of concavities going 80-90m deeper from today's sea level revealed by borings, theye are understood to be tectonic collapses that formed by northwest-southeast and northeast-southwest directional incline-pulsating normal faultlines.

- In age determination with C14 on carbonated plant particles taken from 1270371D-1 no. bore hole's 55.5, 60.0 and 62.0 m and 1270372N-1 bore hole's 41.90m made in Küçüksu brook's reaching to Bosphorus plain within the scope of the project ages that corresponds to Holocene such as 9.380 ± 50 y, 11.050 ± 50 y and 11.100 ± 50 y and 8790 ± 50 y found. In Çengelköy Bekar stream mouth on the other hand 7220 ± 50 y ve 7190 ± 50 y are found by the C14 method age determination on carbonated plant particles taken from 29.50 and 33.00 depths. Consequently Kuşdili Formation is understood to be at Holocene age.

## 4. PREPARATION OF 3D UNDERGROUND GEOLOGY MODEL

Project site's 3 dimensional underground geology model is prepared with EVS/MVS+ARCGIS programs based on 1/2000 scaled geology map prepared within the scope of the project and using boring data, geologic cross sections and formation base contours drawn in the light of these data. During the preparation of the model studies are made based on formations apart from 3 members that cover wide areas. Formations whose models are developed are as follows.

**Chart 4.1 Formations**

| No | Formation | No | Formation |
|---|---|---|---|
| 1 | Alluvium (Quarterner) | 9 | Dpk – Kartal Member (Paleozoic) |
| 2 | Sultanbeyli (Tertiary) | 10 | SDp – Pelitli Formation (Paleozoic) |
| 3 | Kto – Ozantepe Volkaniti (Mesozoic) | 11 | OSy – Yayalar Formation (Paleozoic) |
| 4 | Kty – Yakacık Magmatite Complex (Mesozoic) | 12 | OSyg – Gözdağ Member (Paleozoic) |
| 5 | Ps – Sancaktepe Granite (Mesozoic) | 13 | Oa – Aydos Formation (Paleozoic) |
| 6 | Ct – Thrace Formation (Paleozoic) | 14 | Opk – Kurtköy Formation (Paleozoic) |
| 7 | DCd – Denizliköyü Formation (Paleozoic) | 15 | Opkc – Kocatöngel Formation (Paleozoic) |
| 8 | DCdy – Yörükali Member (Paleozoic) | | |

Additionally, field studies made in the area ( seismic refraction locations, cpt locations, boring locations), structural elements (faultline, etc.) and landslide areas are illustrated in 3d model to enrich presentation content.

Geological sections of NS, EW directional with 2.500m gaps are prepared by EVS/MVS program, and it is possible to take sections from any direction and angle because of the program's feature.

3D underground model developed as a result of the study is shown in Figure 4.1.

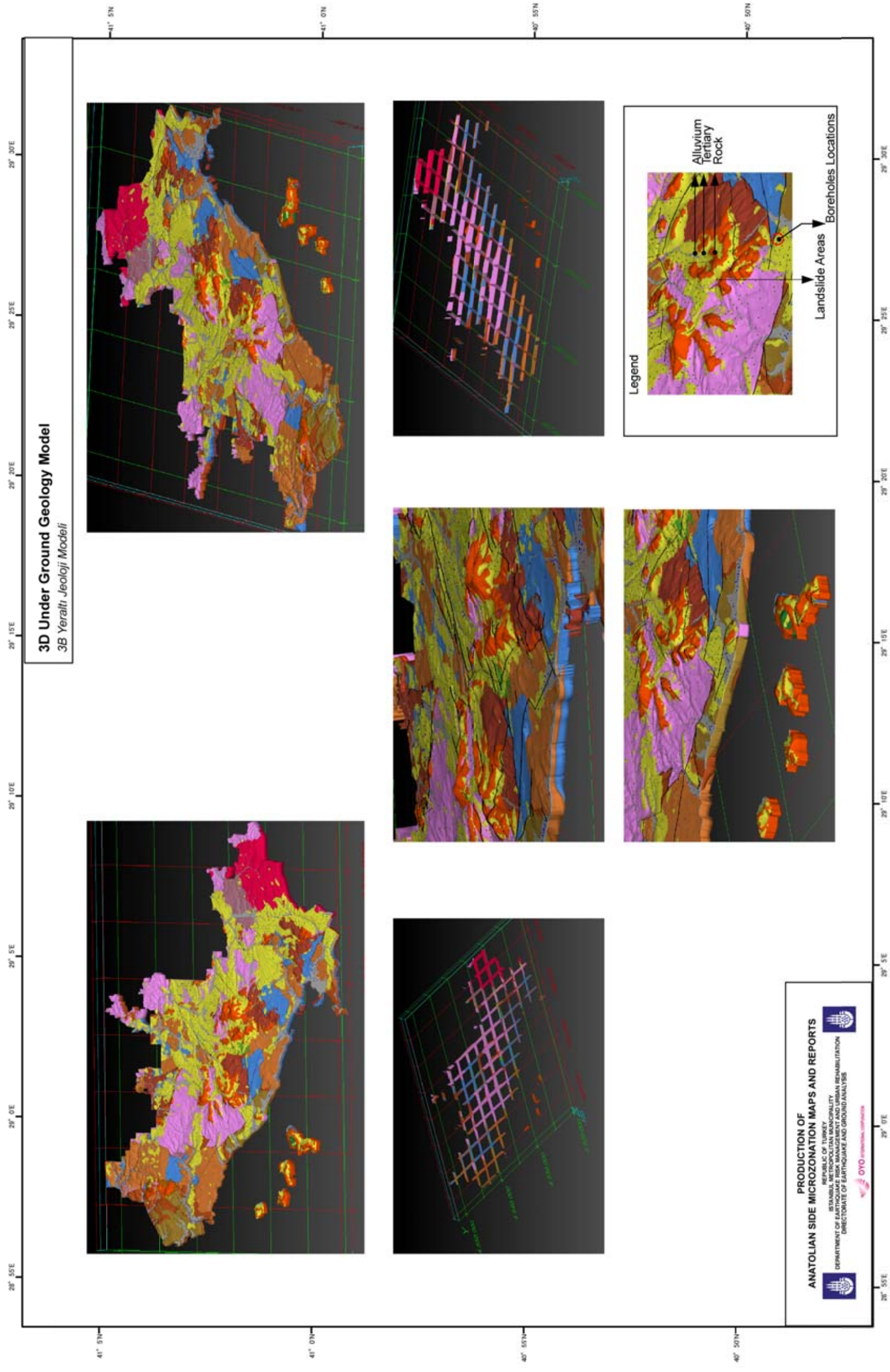



**Figure 4.1 3D Underground Geology Model**

## 5. HYDROGEOLOGY

Hydrogeological maps and sections are prepared by adding geohydrolic and hydrogeological meaning to current geologic and geomorphologic hydrologic information at the end of a pre-enlightment period during which studies belonging to the area are examined within the scope of the project, annual periods with pluvial and dry long years are determined by regional meteorological analysis, underground water depth and peer underground water contours are drawn by utilizing underground water level data that are measured in soil borings, the information provided is used within the context of the Project.

66% of 681.90 mm / year long years precipitation average recycles to atmosphere as a result of evaporation and the remainder from evaporation which is %34 pass into the flow (surface, subsurface, underground flow). While June – September period represents ‘‘Dry Period’’, April – May and October months represents ‘‘Transition Period’’. In November – March period (Pluvial Period) when the soil is waterlogged surface flows are to be expected in any precipitation. Long years (1975 – 2007) meteorological evaluation displays that the area had ‘‘pluvial years’’ in 1978 – 1985 and 1998 – 2005 period, while it had and will have ‘‘dry years’’ in 1986 – 1997 period as before 1977 and from 2006 on. It can be predicted that in case of a re-occurring past periods there will be lesser precipitation every year until 2015 in condition to be within ‘‘dry years’’ which is under long years average, but long years precipitation average will be obtained again in 2017 with the increasing amount of annual precipitation starting from 2015 and in following 2018 – 2025 interval will be ‘‘pluvial years’’ and later will be a ‘‘dry years’’ period. Total rainfall depth’s gradual decrease belonging to January, May, July and December compared to former values measured in ‘‘dry years’’, it’s increase belonging to February compared to former values measured in ‘‘pluvial and dry years’’, total rainfall depth of June’s being more in dry years and less in pluvial years, ‘‘pluvial years’ in which min. precipitation is measured’’ including only 4 months (March, June, October, November), yet ‘‘dry years’ in which max. precipitation is measured’’ including 7 months (April, May, June , July, September, October, November) are all attracted attention.

In the first phase of hydrogeological evaluation and examination, formations that form the area and their members with geohydrolic charactheristics of lihological units that create them in Holocene – Lower Ordovician age range, in other words their underground ater permeability and conductibility features ( presence of clearance, clearance dimensions, presence of relation between clearances and its level) are analysed by building up 53 evaulation units and existence of 4 different main geohydrological environment types is detected. In this detection 1/5.000 and 1/25.000 scaled geology maps based on 1/2.000 scaled geologic database with 1/12.500 and 1/25.000 scaled sections, field observation notes and photos besides trench logs of soil borings have been the main data source. Therefore; geohydrolic environment characterisation of lithological units are made properly, hydrogeology map based on geohydrolic environment types are prepared, hydrogeologic environment (underground water storage areas) types, locations ad general properties from the point of view of geologic sections are identified, places in underground water basin feature are detected, water level presence and depth within trenches in soil borings are given a meaning, underground water peer depth and underground water peer altitude contours are drawn, underground water flow directions and underground water accumulation / depletion areas are marked, underground water areas related to structure bases with one or two basement and deep diggings are identified.

## 5.1 Hydrogeologic Environments

Considering hydrogeology map that totally includes project site and is prepared with a new approach based on ‘‘environmental permeability’’, underground water storage environments which are also called as hydrogeologic environment shape two main hydrogeologic environment type( aquifer , aquitard) exhibiting ‘‘free’’ and ‘‘compressive’’ environment characteristics depending on regional geologic and geohydrolic feautures. These display ‘‘grained’’ and ‘‘rock’’ features from place to place, and also harbor ‘‘perched aquifers’’ that exhibit local underground water accumulation features in different underground levels. A zone (Tuzla – Aydos line)that have a high potential to form underground water basin in the area is predicted. The existence of ’’quartzite aquifer basin’’ that includes underground water in spring water quality and has low hardness depending on the lithology in N half of this line and a limesone aquifer basin in middle and S section of this line are decided worth analysis.

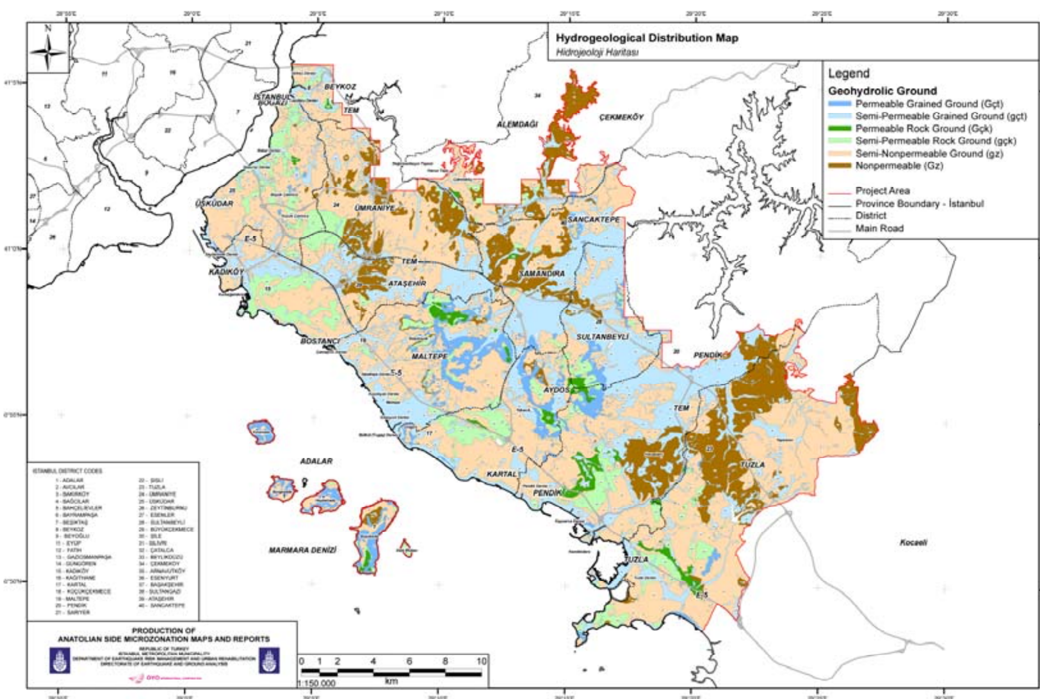



**Figure 5.1 Hydrogeology Map of Research Area**

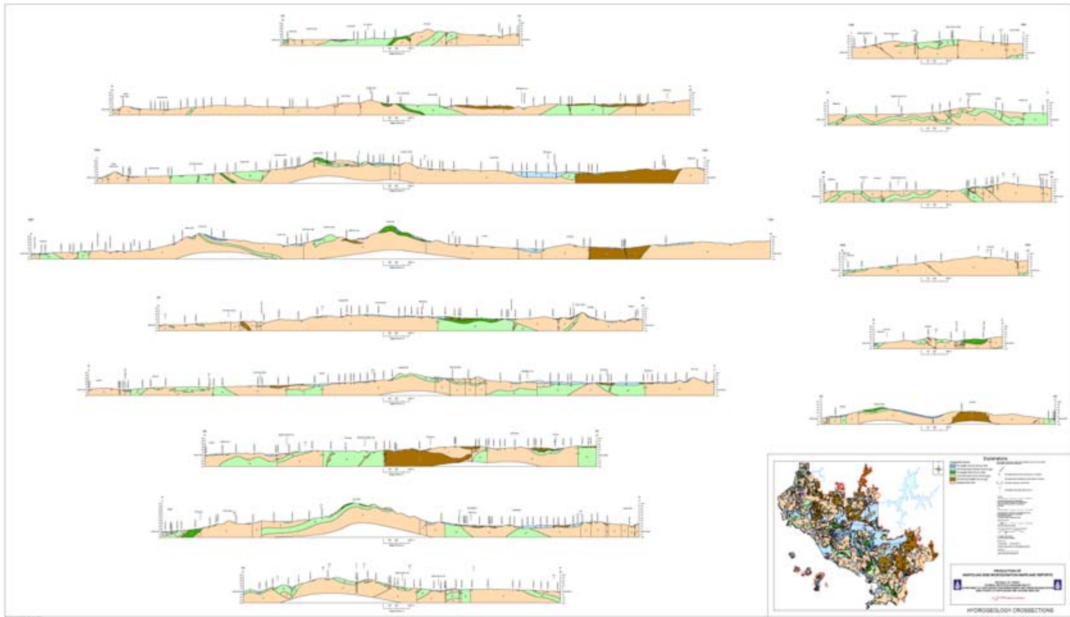


**Figure 5.2 Hydrogeology Sections of Research Area**

Regional general character of aquifers with ‘‘rock environment’’ character in the area is that they are in forms of areas of different sizes, generally narrow / short-long and irregular medium – small expansioned, they are medium – high efficiency free and compressive aquifer featured from place to place , since open to contaminaion and swiftly can be contaminated taking precautions and protecting directly catchment areas is easy – very hard, suitable – very suitable (even in spring water quality) for drinking, research and evaluation technics requiring medium – deep borings for underground water production are relatively hard, slow and expensive. Moreover, aquitards that are extensively widespread and medium – low underground water efficient are reaching to areal dimensions from place to place and they are significant ‘‘in proportion to expansion width’’.

Perched aquitards in property of local underground water accumulations with low – very low storage that shape expansive permeable and semi permeable levels – zones in different levels and take place within Impermeable (Gz) and Semiimpermeable (gz) environments among geohydrolic environments in the area are detected. Most of the inside trench water levels measured within soil borings belong to such kind of perched aquitards.

Underground waters in the Project site are predicted to be rich in ions such as SiO2, Na+, K+ , SO4=, Fe+2-3 , CO3= , HCO3- depending on the principle that ‘‘underground water composition is not irrelevant to the lithological units’ chemical composition that forms the geohydrolic enviroment in which it moves’’.

## 5.2 Sources and Spring Waters

They are generally in qualty similar to the lithological units’ chemical composition water where they outflow, in type of ‘‘seam and contact’’ source within permeable and/or semipermeable units, and in type of ‘‘crack and faultline’’ source within impermeable and/or semiimpermeable units and in character of low – very low flow rated underground water discharges. In times when urbanization is not widespread the ones with convenient flow continuity and flow rate are used as herdsman taps or as wells for small village needs. Within the project site 3 of the spring water facilities are managed by tenants and 5 of them from a total of 8 that are in control of Istanbul Special Provincial Administration are known to be not leased out. The ones that are under a management has water hardness and flow rate of 1.0 – 2.5 0F and 0.41 – 2.5 lt/sec, and the ones that are not yet leased out by that date have 1.5 – 5.9 0F and 0.03 – 0.11 lt/sec respectively.

## 5.3 Underground Water Level

A total of 5029 soil borings are made wihin the scope of the project and between 1 – 16 number of ‘‘inside trench water level’’ deph measurement are done for them. Within the context of regional underground water level properties research; separation according to the geohydrolic environment types in which they are opened and determining actual underground water level, selecting lowest underground water level values belonging to ‘‘Pluvial Period (November – March) wih the help of measurements of borings, and drawing of peer deph and peer altitude contours for every geohydrolic environment type and area separately are all performed.

Both annual monthly changes and annual meteorological periodical(pluvial, transition, dry) hydrogeological conditions of underground water level presence’s regional behaviour within different geohydrologic environment and its condition according to long years precipitation average are analysed with the help of graphics and it is understood that water depths within ‘‘Permeable Grained Environment + Semipermeable Grained Environment’’ are in most passive charactet parallel to annual precipitation, water depths in more less passive ‘‘Permeable Rock Environment + Semipermeable Rock Environment’’ and ‘‘impermeable Environement + Semiimpermeanle Environment’’ also prove the local perched aquitard presence with their parallelism with each other, and because of their geohydrolic features precipitation and generally meteorological conditions are deferred either to effect ‘‘Impermeable + Semiimpermeable’’ environments with delayed leakage or to effect ‘‘permeable Rock + Semipermeable Rock’’ environments with catchment from distant areas.

Regionally, underground water flow directions around brook valleys and beds are into the brook line, in other words the are directed in order to feed underground brooks. On the other hand hydrolic inline values can ben different depending on the presence of several small dimensioned and unconnected local underground water accumulation environments ( mostly in property of perched aquitards) which leads to underground water flow directions very different orientation in small distances. Regional underground water accumulation and release areas cover lots of locations that are squeezed into local small areas. When these hydrogeologic properties are to be known it is more realistic to make a specific evaluation only for that area.

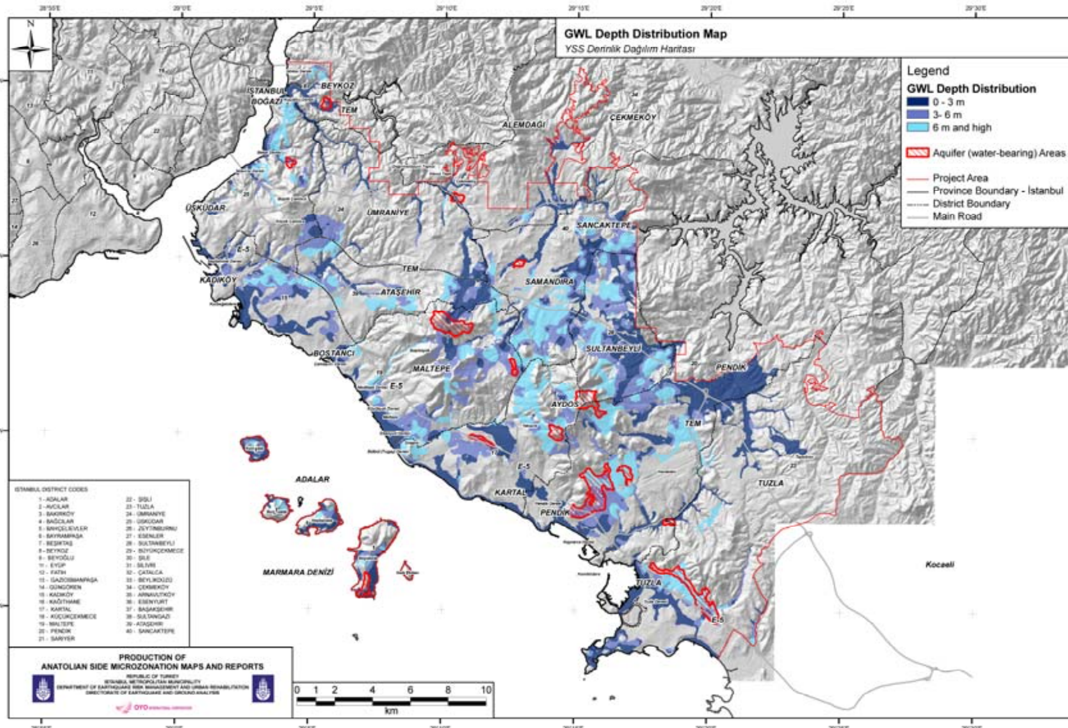



**Figure 5.3 Engineering Purpose Underground Water Depth Map**

## 5.4 Conclusion

1. As a Hydrogeologic Mapping method the identification of ‘‘geohydrolic environment types’’ tha explains the environmental permeability of lihological units should constitute a base as it is in this hydrogeological research ever after and ‘‘best aquifer, weak aqufer’’ approach should be quitted. Because his method makes it possible to reach extremely significant findings that are impossible to be found by former method.

2. Besides ‘‘geology’’ data that is the main focus point in Hydrogeologic studies the necessity of integration with geomorphology, hydrology and especially meteorology database should be carefully considered.

3. The importance and indispensability of Hydrogeological studies in ground risk analyses and methods are understood again within the scope of this research.

4. Annual and long years meteorological periods are significantly taken into consideration for both use of water and ground environments surface and underground water flow, flooding and overflow type hydrologic originated risk analyses, underground water levels being in highest (close to surface) and overground – underground drainage works timing. It is vital to know their positive or negative potential affect in case of a possible Istanbul earthquake .

5. Aquifers in the area should be targetted to produce underground water production after a earthquake , and these underground storage environments geometrical such as presence, location and dimension, geohydrological such as underground water movement and environment hydrolic parameters, existence such as underground water efficiency, reserve, above ground – underground

accumulation conditions, continuity as protection areas, water quality and response to polluters ,technic as boring technics and technology parameters should be separately analysed. Moreover aquitards in the area should be protected no matter how low their efficiency are and utilization possibilities should be investigated.

6. Annual meteorological periods having steady and regular effect on areal underground water level and exhibiting dimensional changes depending on geohydrolic environment type character are determined and therefore it is specified wihin the scope of the project that there can not be a water level which falls in same amount any place any time

7. By potential underground water basins' hydrogeologic analyses, definition of the type of technics, its quality, proportion and continuity to produce underground water in case of possible post earthquake is essential to know within the scope of the afterwards strategies.

## 6. JEOTECHNİCS PURPOSE LABORATORY TESTS

Maximum, minimum and average values of engineering parameters belonging to formation and members are specified by evaluating laboratory test results conducted on soil and rock samples taken from the borings. These values constitute a base for other analyses in micro-zonation study.

Classification charts (Plasticity index, consistency index, compression index, etc.) belonging to formation and members do not include field observations. It should not be forgotten that Soil Mechanics Tests are only conducted on units that possess sand – clay and silt lithologies with Insitu Tests of lithologies in soil property. Nevertheless it has been detected by the field observations that some units consist of abundant gravel and blocky material. Altıntepe member of Sultanbeyli formation is a very good example for such kind of units. For this reason utilization of this values in analysis phase should be performed within the context of field and boring results. While evaluating this results in analysis within the scope of the Project, besides lab results of formation and members definitive dominant values of this formation and members are also taken into consideration.

Total result chart including average values of all lab tests conducted on rock and soil lithologies forming the Project site are given in Chart 6.1.

**Chart 6.1 Lab Tests**

| FORMATION / MEMBER | NATURAL WATER CONTENT TEST | SIEVE ANALYSIS TEST (%) | | | HYDROMETRE (%) | | TEST of CONSISTENCY LIMITS | | | CONSOLIDATION ($kg/cm^2$) | SWELLING (%) and SWELLING PRESSURE TEST ($kg/cm^2$) | | SHEAR STRENGTH and STRESS DEF. TESTS | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | UNCONFINED COMPRESSION TEST | | TRIAXIAL COMPRESSION TEST ( UU ) | |
| | ( Wn) (%) (Ort) | CLAY | SANDY | GRAVELLY | CLAY | SILTY | LL | PL | PI | | (%) | ($kg/cm^2$) | qu ( $kgf/cm^2$) | Cu (qu/2)($kgf/cm^2$) | C ($kgf/cm^2$) | Ø ( Degree) |
| Old Beach Deposit( Qpl ) | 20,04 | 23,85 | 60,09 | 14,11 | 19,29 | 19,34 | 28,21 | 13,87 | 14,34 | 0,0302 | 0,626 | 0,0188 | 1,09 | 0,51 | 0,34 | 5,90 |
| Alluvium ( Qal ) | 17,66 | 49,58 | 39,40 | 13,70 | 23,43 | 17,07 | 28,55 | 13,01 | 15,53 | 0,0322 | 0,448 | 0,023 | 1,40 | 0,70 | 0,53 | 11,77 |
| Old Alluvium( Qale ) | 17,57 | 57,11 | 33,34 | 9,55 | 19,95 | 21,00 | 26,17 | 12,89 | 13,28 | 0,03979 | 0,405 | 0,014 | - | - | - | - |
| Beach Deposit( Qs ) | 18,39 | 40,35 | 34,18 | 25,48 | 22,10 | 12,94 | 24,95 | 15,75 | 9,20 | - | - | - | - | - | - | - |
| Kuşdili Fm ( Qkş ) | 24,99 | 56,02 | 35,20 | 8,79 | 20,36 | 20,89 | 29,02 | 14,65 | 14,37 | 0,040 | 0,534 | 0,021 | 0,887 | 0,445 | 0,45 | 10,89 |
| Abduş Gölü Member ( Qkşa ) | 16,29 | 58,28 | 28,26 | 13,46 | 30,04 | 19,04 | 28,49 | 11,49 | 17,00 | 0,0341 | 0,964 | 0,0316 | - | - | - | - |
| Sultanbeyli Fm ( Ts ) | 16,83 | 66,75 | 26,79 | 6,46 | 23,37 | 17,89 | 27,92 | 12,44 | 15,48 | 0,0159 | 1,248 | 0,0561 | 2,29 | 1,14 | 0,76 | 14,95 |
| İkiz Tepeler Member( Tsi ) | 16,33 | 41,44 | 52,75 | 5,81 | 24,00 | 17,98 | 31,30 | 16,80 | 15,50 | - | - | - | - | - | - | - |
| Altıntepe Member ( Tsa ) | 16,69 | 65,72 | 30,94 | 14,00 | 20,99 | 17,74 | 28,18 | 12,00 | 16,18 | 0,0176 | 0,992 | 0,0498 | 1,85 | 0,925 | 0,91 | 6,20 |
| Tuğlacıbaşı Member ( Tst ) | 18,11 | 67,88 | 24,11 | 8,01 | 25,11 | 15,92 | 29,74 | 13,35 | 16,39 | 0,0166 | 1,644 | 0,0573 | 1,99 | 0,99 | 0,589 | 16,78 |
| Dudullu Member ( Tsd ) | 23,15 | 83,47 | 13,57 | 2,96 | 25,72 | 17,05 | 30,55 | 15,14 | 15,41 | 0,0167 | 1,215 | 0,0508 | 2,32 | 1,11 | 0,51 | 59,29 |
| Orhanlı Member ( Tso ) | 16,18 | " | 23,06 | 6,98 | 26,77 | 14,89 | 31,55 | 11,92 | 19,63 | 0,0157 | 1,441 | 0,0609 | 2,36 | 1,18 | 0,77 | 13,95 |

**Chart 6.2 Laboratory tests on Rock units average values**

| FORMATION TYPE | PHYSICAL INDEX - AVERAGE VALUES | | | | | ONE AXIS - AVERAGE VALUES | | THREE AXIS - AVERAGE VALUES | | | PULLING-AVR. VAL. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | γk | γd | $n_{ef}$ | e | Wa | Pressure Resistivity | E Module | $\sigma_b$ | c | ϕ | $\sigma_ç$ |
| | ($gr/cm^3$) | ($gr/cm^3$) | (%) | (%) | (%) | ($kg/cm^2$) | ($kg/cm^2$) | ($kg/cm^2$) | ($gr/cm^2$) | (°) | ($kg/cm^2$) |
| S.Graniti | 2,57 | 2,60 | 2,51 | 2,59 | 0,98 | 87 | 29000 | 27,0 | 12,0 | - | - |
| Trakya | 2,54 | 2,61 | 7,50 | 8,39 | 3,06 | 435 | 100500 | 163,3 | 24,5 | 54,2 | 29,0 |
| Acıbadem | 2,43 | 2,55 | 11,60 | 13,47 | 4,92 | 273 | 13000 | 440,0 | 25,0 | 52,0 | 39,2 |
| Denizliköy | 2,60 | 2,64 | 3,86 | 4,06 | 1,51 | 507 | 138333 | 349,3 | 42,5 | 53,9 | 43,2 |
| Ayineburnu | 2,61 | 2,64 | 3,00 | 3,18 | 1,16 | 299 | 65000 | 215,4 | 20,4 | 53,2 | 38,3 |
| Kartal | 2,54 | 2,61 | 7,58 | 8,43 | 3,09 | 256 | 44364 | 278,9 | 22,8 | 51,1 | 29,0 |
| Kozyatağı | 2,55 | 2,61 | 6,12 | 6,79 | 2,51 | 619 | 136750 | 474,2 | 44,4 | 56,9 | 34,8 |
| Pelitli | 2,62 | 2,65 | 3,60 | 3,85 | 1,41 | 540 | 149143 | 520,3 | 44,3 | 59,4 | 45,9 |
| Soğanlık | 2,64 | 2,67 | 3,59 | 3,84 | 1,40 | 468 | 92250 | 433,4 | 29,3 | 55,3 | 46,8 |
| Sedefadası | 2,46 | 2,54 | 7,92 | 8,89 | 3,35 | 326 | 69000 | 362,0 | 30,0 | - | 64,9 |
| Şeyhli | 2,59 | 2,64 | 5,02 | 5,39 | 2,00 | 748 | 132667 | 484,3 | 73,2 | 51,7 | 62,2 |
| Gözdağ | 2,55 | 2,63 | 8,65 | 10,09 | 3,60 | 564 | 78800 | 350,6 | 35,0 | 54,0 | 46,8 |
| Aydos | 2,54 | 2,58 | 4,00 | 4,45 | 1,68 | 574 | 92250 | 505,0 | 64,4 | 56,1 | 47,1 |
| Manastır Tepe | 2,41 | 2,50 | 9,15 | 11,02 | 4,20 | 594 | 111500 | 381,0 | 26,1 | 55,6 | 35,1 |
| Kurtköy | 2,58 | 2,63 | 5,39 | 5,86 | 2,15 | 289 | 53591 | 242,8 | 23,3 | 52,7 | 32,4 |
| Bakacak | 2,71 | 2,74 | 2,05 | 2,09 | 0,76 | 476 | 110500 | 516,7 | 41,0 | 63,0 | 62,8 |
| Kocatöngel | 2,57 | 2,65 | 7,14 | 7,85 | 2,83 | 185 | 18000 | 118,0 | 26,0 | 50,0 | 49,7 |
| Volkanit | 2,44 | 2,54 | 10,48 | 11,90 | 4,36 | 551 | 62000 | 520,7 | 25,8 | 57,5 | 43,2 |

## 7. GEOPHYSICS

Researches of geophysics engineering applied during micro-zonation studies consist of methods to obtain underground geophysics sections and physical properties. In this context, there has been seismic refraction and reflection, refraction – microtremor (ReMi), array microtremor, SAPC, MASW (Multi channel spectral analysis of surface waves), SASW, trench geophysics researches, electricity resistivity methods, ground radar (GPR) studies, etc. are conducted. Selection of method and approach among these is made considering lithology of the project site, its topography, structuring density and industrial noise and effects alike. It is predicted that geophysics researches should serve following eight purposes:

1) Definition of 250m x 250m cells (grid) geophysics features,
2) Definition of rock depths in terms of engineering,
3) Detection of filling areas' limits and depths,
4) Examination of slope stability,
5) Understanding of dominant ground period,
6) Obtaining AVs30 map for İstanbul damage distribution analysis,
7) Determination of discontinuties,
8) Obtaining earthquake parameters such as frequency, magnification.

Distribution of geophysics studies conducted in Project site are shown in Figure 7.8 and its details are as follows:

- Seismic Refraction Line – 4.132 in total
- Surface Wave Method ( ReMi/MASW) – 4.132 in total
- Seismic Reflection Line – 8 lines, 14.125 m.
- Inside trench seismic (Ps Logging) – 504 Spots (2843m depth, 9121.4m shallow)
- Electricity Resistivity Method
- 2 Dimensional Electricity Studies
- 2 Dimensional Seismic Refraction Studies
- Microtremor Measurement – 30 Spots
- Dominant Period Studies – 304 Spots
- 297 Spots Frequency, Soil Magnification Studies

During microzonation project Avs30 distribution map is found by slide wave speed profile's (Vs) 30 meters of upper side thickness calculated by weighted mean Vs value that is calculated by using ReMi that is made for rock and soil units in project site, MASW, inside trench seismic studies (PS Logging), seismic reflection study and boring data series. Avs30 values are reached by using he formula below.

$$AVs30 = \frac{\sum(H_i)}{\sum_{1}^{i}\left(\frac{H_i}{Vs_i}\right)}$$

$\sum(H_i) = 30$ m.

$H_i$ : Layer thickness of every layer forming upper 30 meter (m)

$Vs_i$: Vs value (m/sec) of every layer forming upper 30 meter

AVS30 Distribution Map is shown in the Figure 7.1.

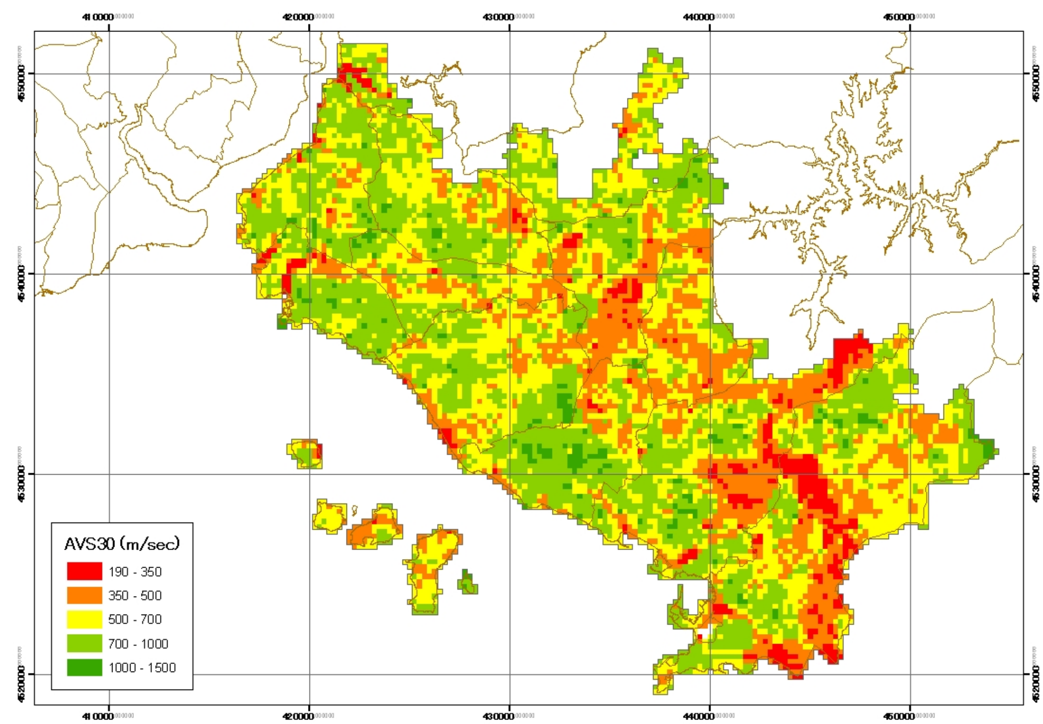



**Figure 7.1 Average S wave speed for upper 30m depth**

Soil classification maps are prepared by using same data series apart from Avs30 map according to Turkish Earthquake Regulations and NEHRP (American Standarts), EuroCode8 (European Union Standarts). Figure 7.2 is the soil classification map according to NEHRP and Figure 7.3 is soil classification map according to Turkish Earthquake Reguations.

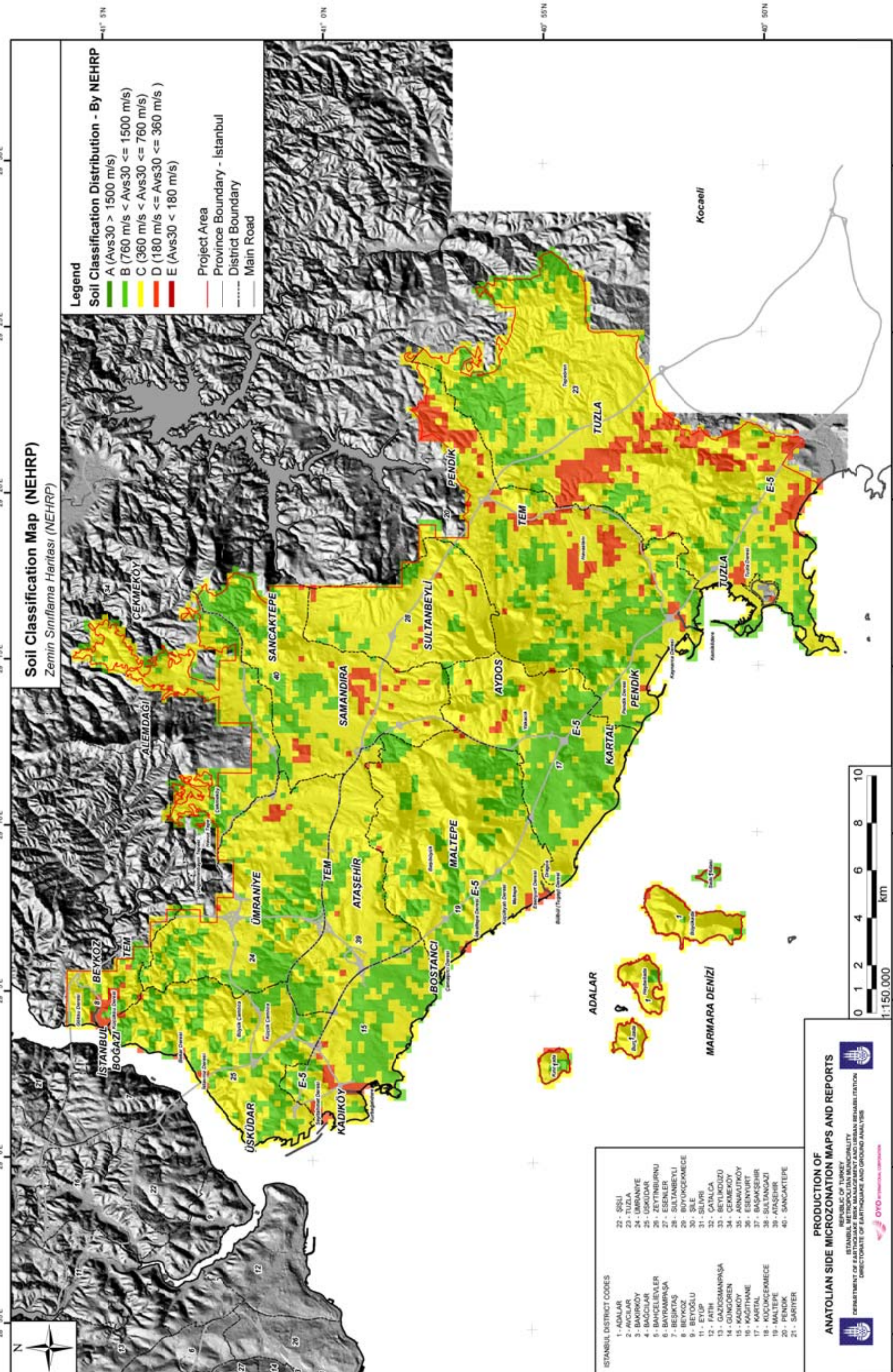



**Figure 7.2 Soil Classification Map according to NEHRP**

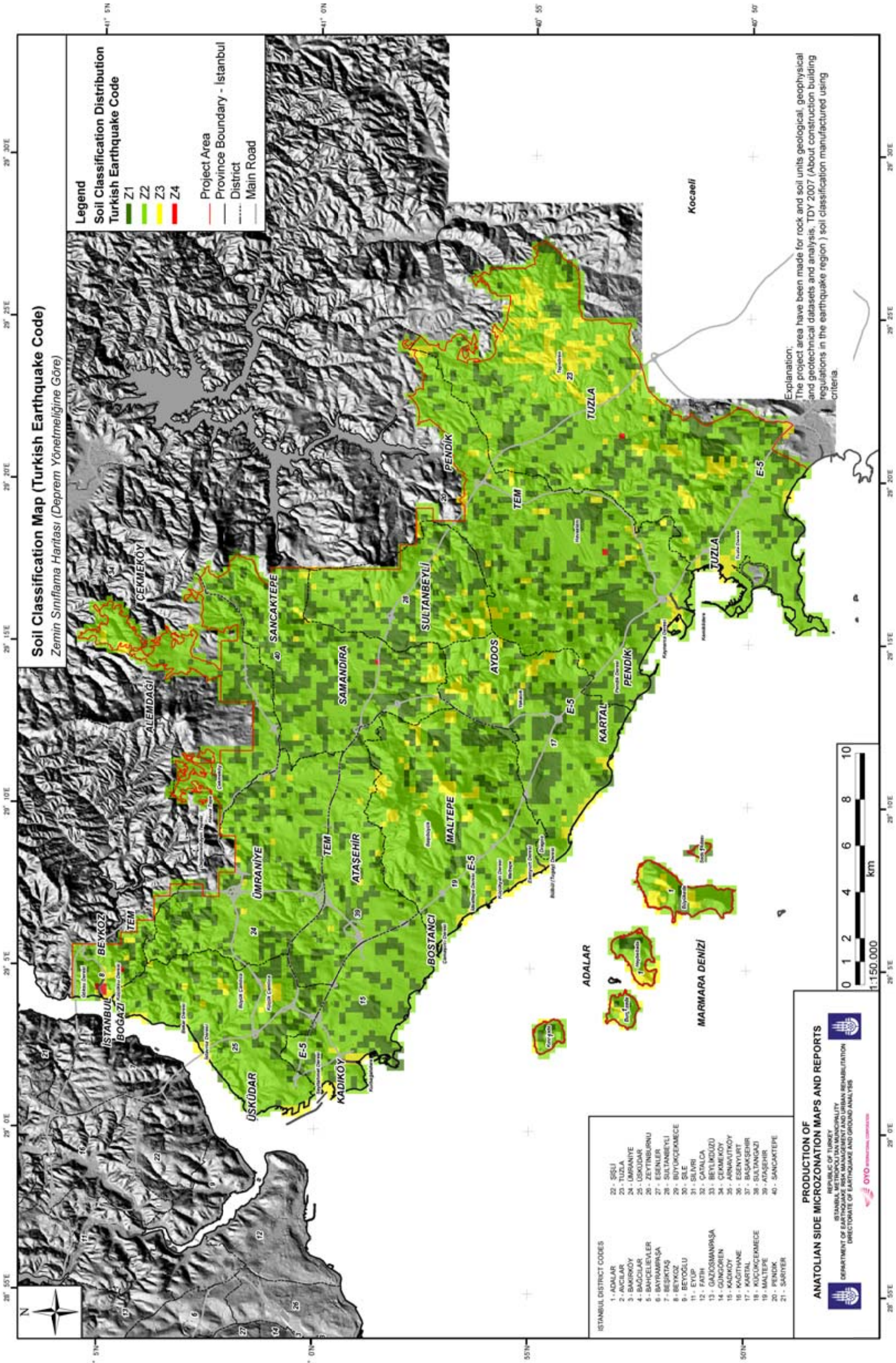



**Figure 7.3 Soil classification map according to Turkish Earthquake Reguations.**

There has also been geophysics studies conducted in order o classify units which are not in the Project. This studies constitute a base for soil modelling based on earthquake danger maps and damage distribution analyses.

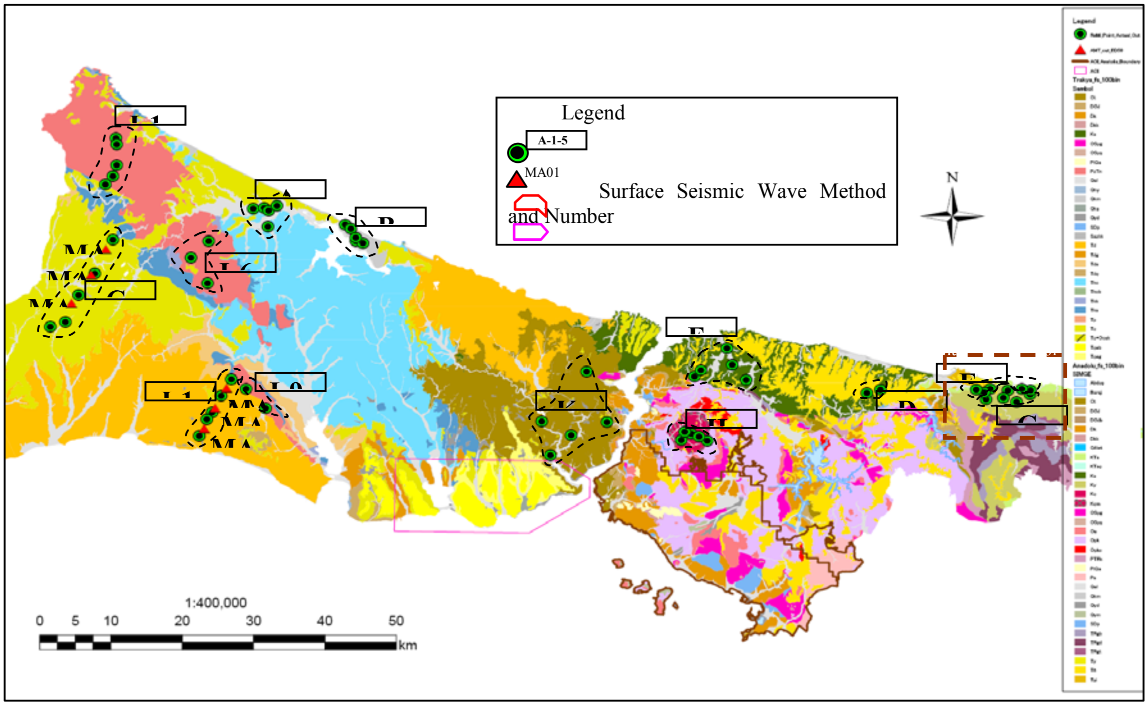



**Figure 7.4 Geophysics Studies made for geologic units classification that are not in the Project**

Apart from this, geophysics studies in artificial filling and lanslide fields (area distribution and depth oriented) are also conducted and great assets to the Project are obtained.

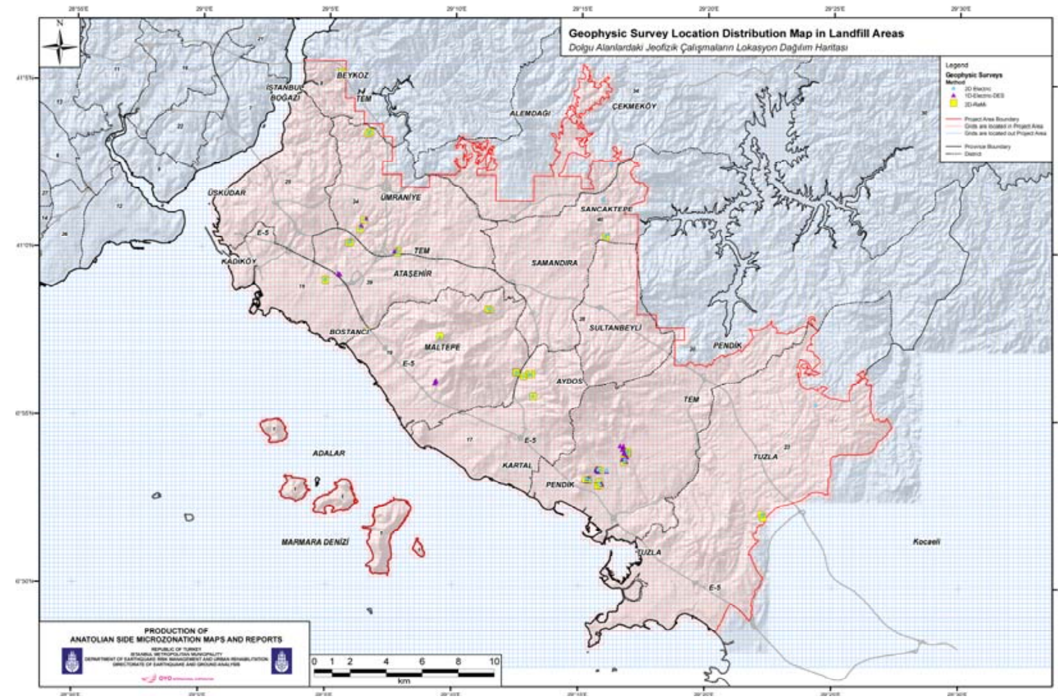



**Figure 7.5 Geophysics Studies Conducted in Artifical Filling Areas**

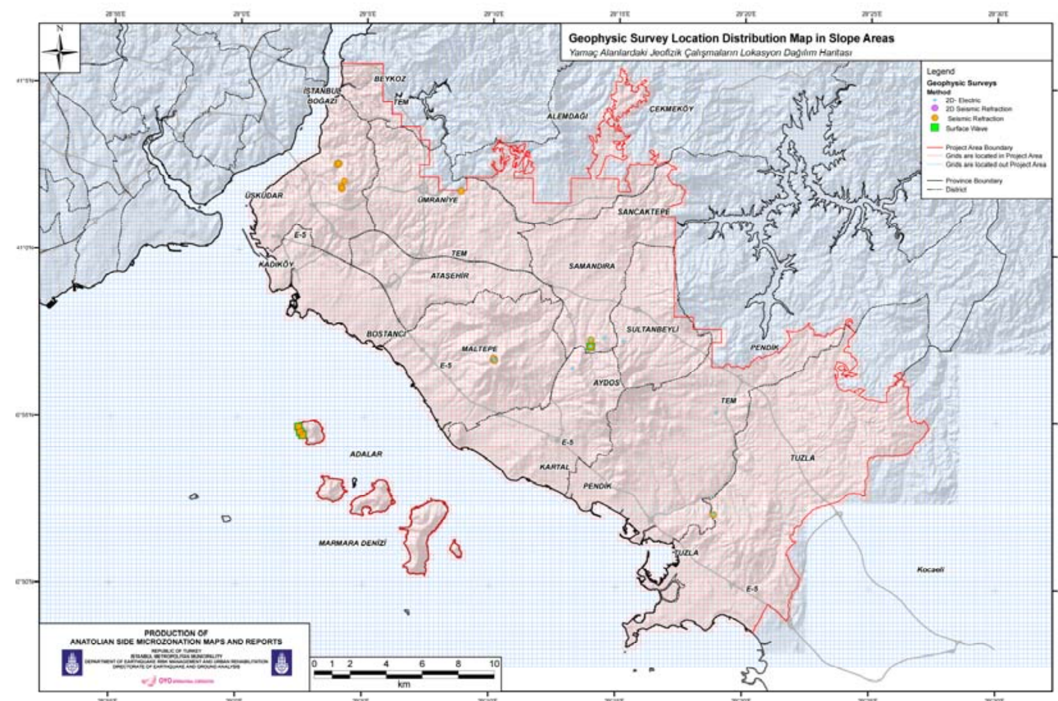



**Figure 7.6 Geophysics Studies Conducted in Slopes (Landslide)**

Moreover, 2 Dimensional Electricity and Seismic Studies and Seismic reflection studies in order to specify Faultline and discontinuity researches and geophysics bed rock depth's distribution.

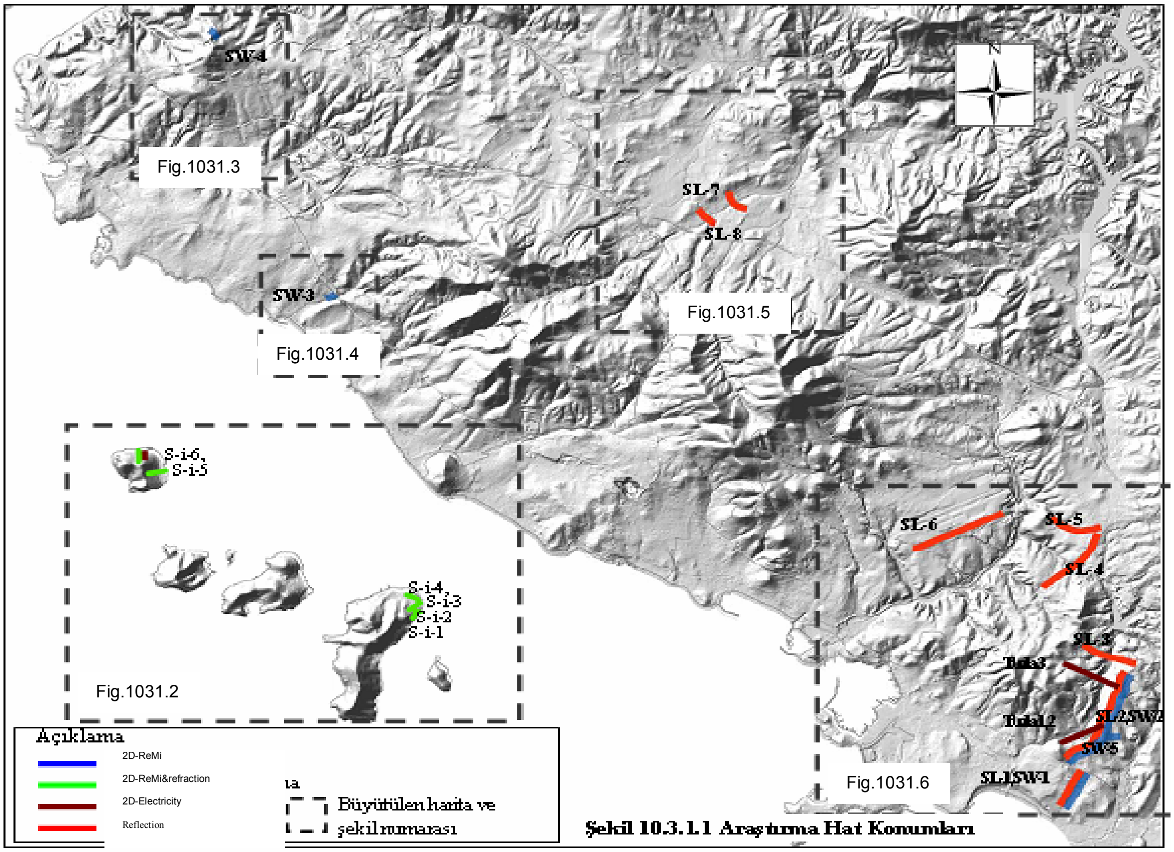



**Figure 7.7 Geophysics Studies Conducted in order to specify Bed rock Depth**

One of the most important puposes of geophysics studies is that to define bed rock depth distribution. All of ReMi, MASW, seismic reflection, inside trench seismic (Ps logging), 2D electricity and 2D seismic studies are used in order to determine geophysics bed rock (Layers with more than 760m/s S Wave speed) distribution. Bed rock distribution obtained from geophysics studies is given in Figure 7,8

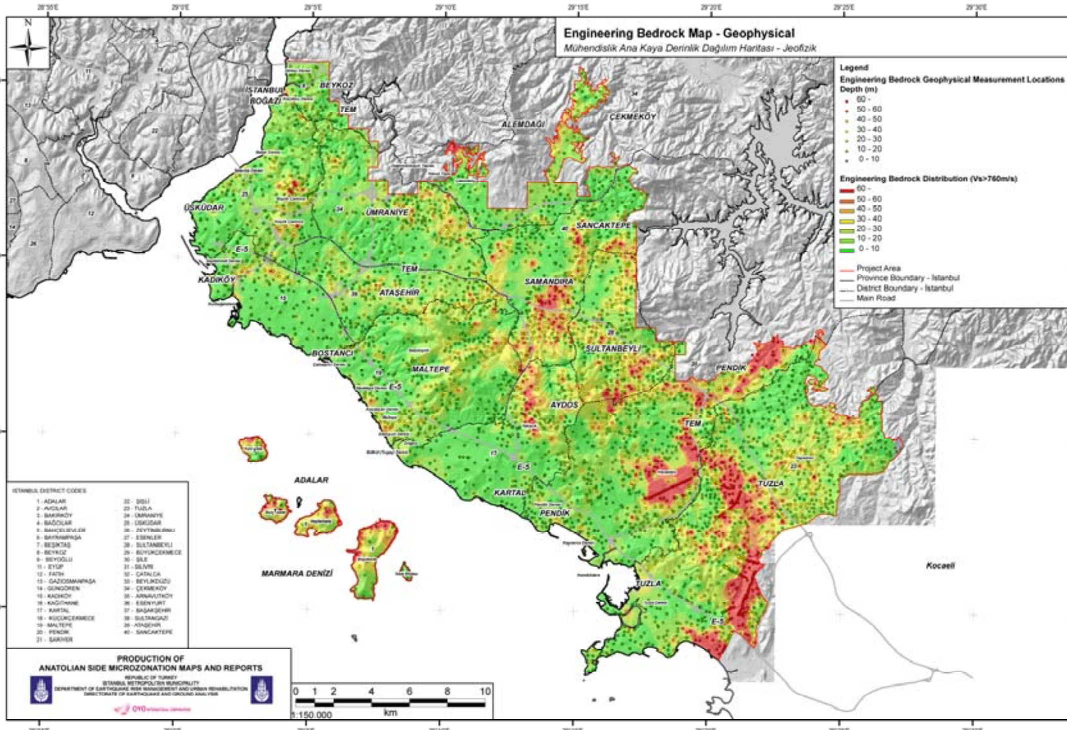



**Figure 7.8 Engineering Bed rock Distribution According to Geophysics Measurements**

IT IS OBSERVED THAT THE GEOPHYSICS BED ROCK DISTRIBUTION MAP IS MOSTLY (75 -90 %) SIMILAR TO GEOLOGY MAIN ROCK DISTRIBUTION MAP PREPARED BY BORINGS.

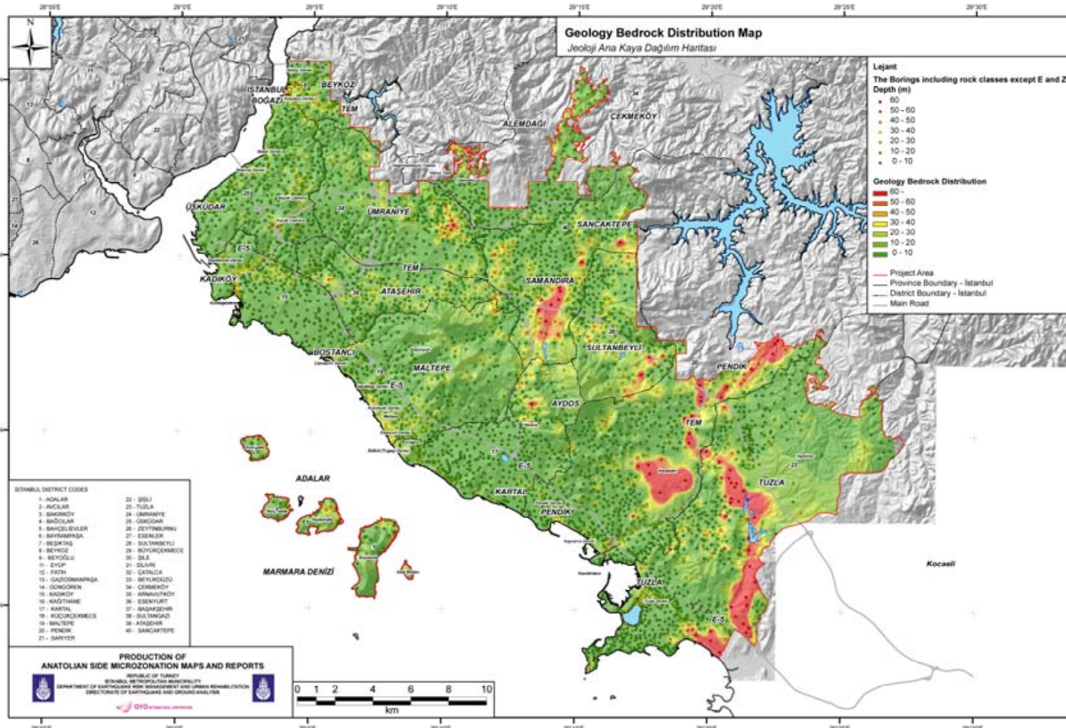



**Figure 7.9 Geology Bed rock distribution Map**

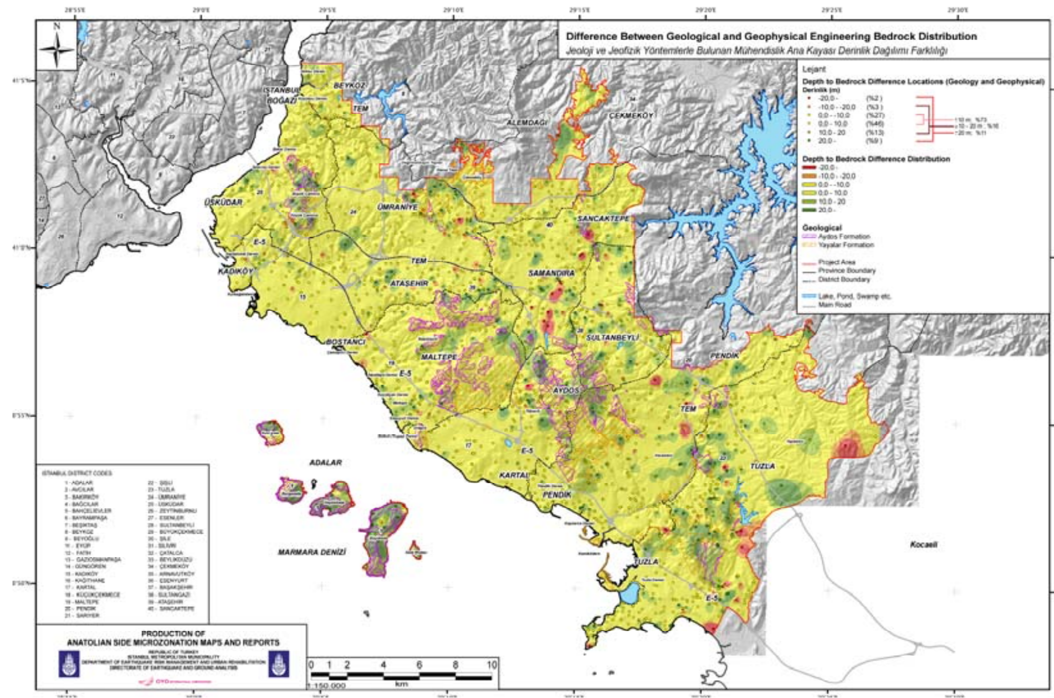



**Figure 7.10 Difference of Engineering Bed rock Depth Distribution found by Geology and Geophysics Methods**

# 8. ENGINEERING PROPERTİES OF SOIL AND ROCK TYPES

Formations that create rock environment in research area are stratigraphically Paleozoic aged Kocatöngel, Kurtköy, Aydos, Yayalar, Pelitli, Pendik, Denizliköy and Thrace formations. Moreover, there are Mesozoic aged volcanites are present and these rock units crop distribution is specified to be 61%. Soil environments on the other hand are forming Neogene aged Sultanbeyi formation and quaternary aged current accumulations with crop distribution of 39% ( Figure 8.1). There has been some studies made in order to find soil and rock types' engineering properties which take place in the area. Details about the studies are as follows.

## 8.1 Rock Environments

1- Measurements in natural and artificial mostras that are convenient for measurements in direction to detection of dominant layer and joint systems of rock units are made and it is tried to specify the relationships between discontinuity attitude and natural slopes by analysis. It is observed that in convenient to measurement mostras partaking all of the area a total of 2.525 layer-directional-slope are present, and according to the results of meaurements in a total of 1910 joint systems all dominant discontinuity's directions are NW-SE and NE-SW. This result also exhibits convenience with area's tectonic progress.

2- Besides these measurements in surface mostras boring studies in rock's weathered sections are made to obtain information about weathering level, thickness and expansion. By specifying weathering and strenght of cores obtained from borings rock quality classification is made according to ISRM(1981) ( Chart 8.3). As a result of this classification, most of (51.5%) the rocks surfacing in Project site are C class rocks (Chart 8.1). Among rocks surfacing in Project site, Volcanic Dyke's 34%, Kurtköy Formation's 33%, Sancaktepe Granite's 98% is E and Z class. Rock classification ratios belonging to rock formations are given in Chart 8.1 and their areal distribution is given in Figure 8.1.

**Chart 8.1 Rock Class Distribution**

| Rock Class | Facile Distribution (%) |
|---|---|
| A+ B | 8 |
| C | 51,5 |
| D | 14,5 |
| E + Z | 26 |

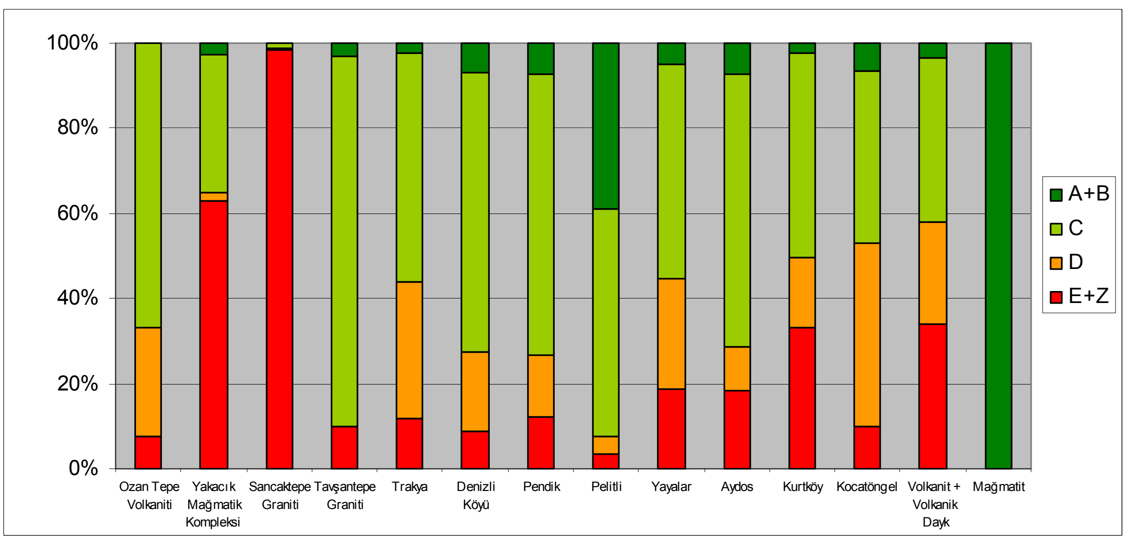
Note: Ratios are calculated according to rock environment areas.

**Chart 8.2 Weathering Strenght Chart**

| Rock Classification | | | | | | |
|---|---|---|---|---|---|---|
| Weathering / Strength | wI | wII | wIII | wIV | wV | wVI |
| rIV - rV | A | B | C | D | E | Z |
| rIII | C | C | D | D | E | Z |
| rII | D | D | D | E | E | Z |
| rI | E | E | E | E | E | Z |

A and B class rock's being in very low amount and surfacing in all of the area roughly is the reason why they are illustrated as a single group. E and Z classes on the other hand are unified in single group because of exhibiting similar engineering properties.

**Chart 8.3 Rock Class Distribution Belonging to Rock Formations**



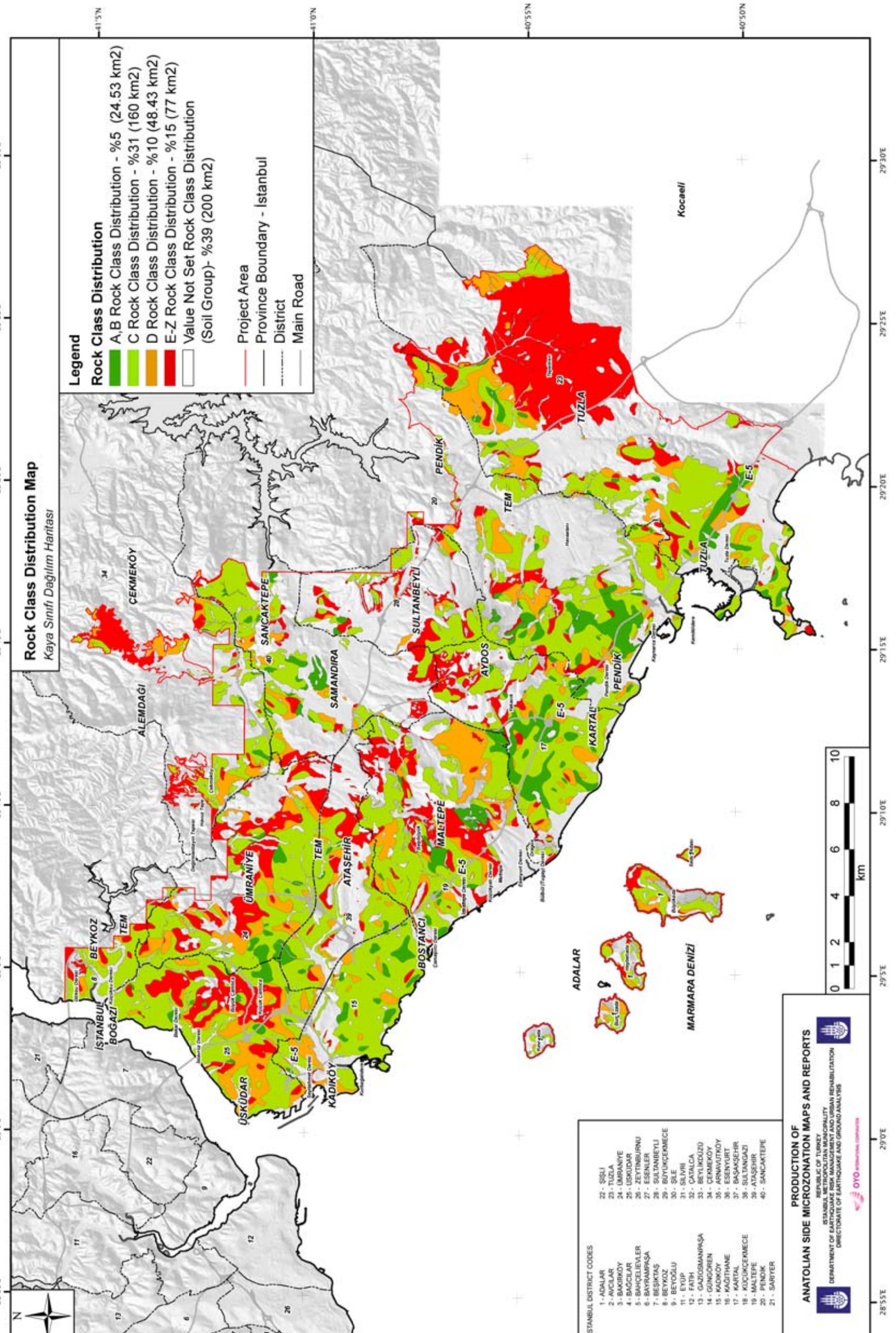



**Figure 8.1 Soil and Rock Environment Distribution Map**

3- There have been los of borings made to found bed rock depths in areas where the bed rock in project site is covered by current and tertiary sediments. Bed rock Depth Map is prepared by specifying these borings entering depths to the bed rock (Figure 8.2). In this map places where bedrock is buried and bedrock depths and expansions are illustrated. According to this map deepest place is detected to be 162m where bedrock is buried.

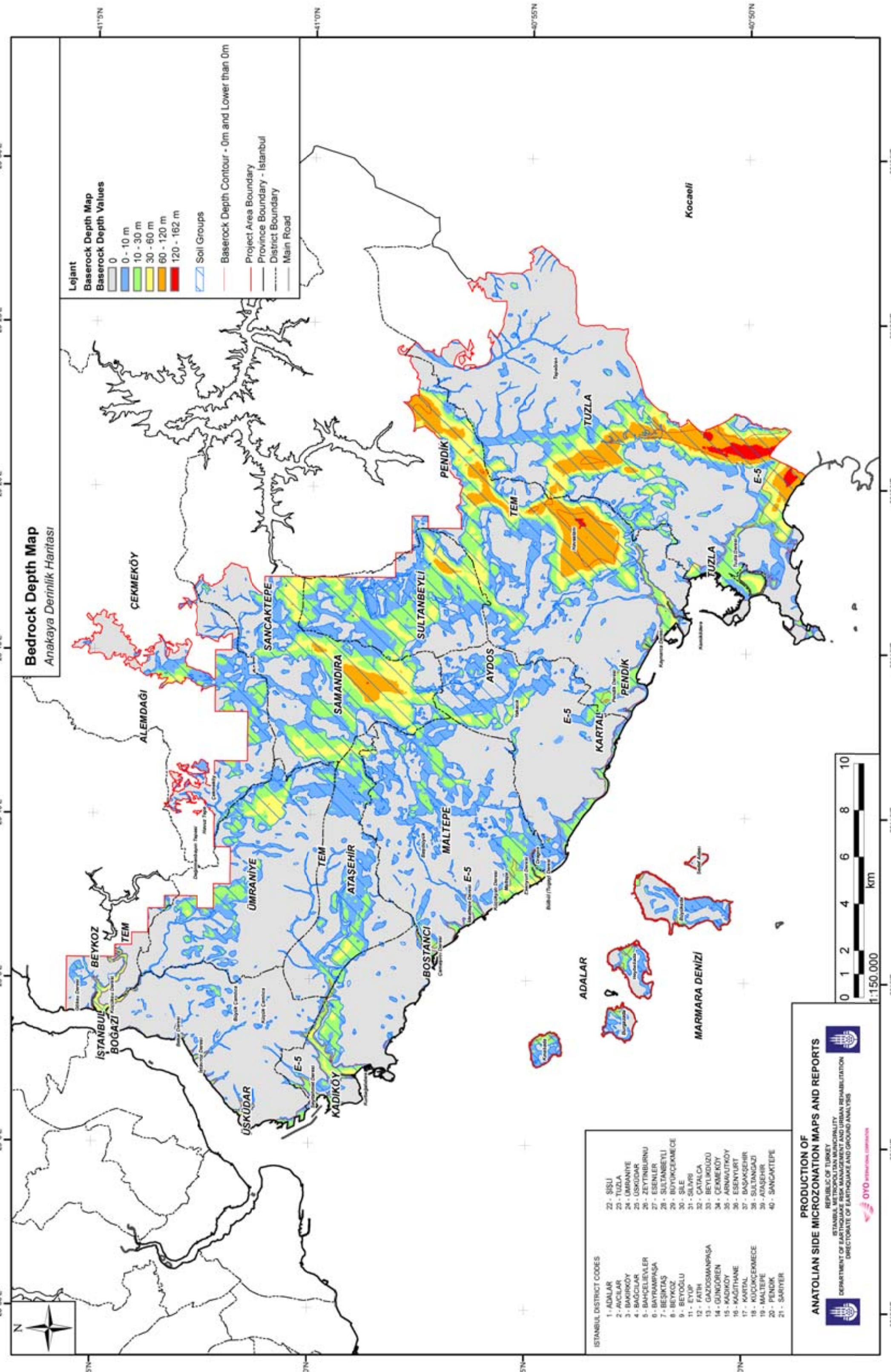



**Figure 8.2 Bedrock Depth Map**

## 8.2 Soil Environments

Current talus and Sultanbeyli Formation's expansion exhibiting areas are mapped as soil distribution area. These areas area evaluated based on SPT N value and depth.

Very Soft and very Loose soils can be seen in Kusdili Formation and Alluvium areas. Zonation is made by using borings that cut sections of this areas whose thickness is more than 10m and average N values are less than 10. Soft soils on the oher hand are seen in areas where Kuşdili Formation, Alluvium and Sultanbeyi Formation exhibits expansion. Average N values of these areas are between 10 and 30, and borings with more than 10m of thickness are used in zonation.

Accordingly, very soft-soft soils are generally observed in stream mouths where Kuşdili Formation and Alluvium exhibits expansion in plains. Soft soil thickness is much especially in Tuzla, Kadıköy and Göksu areas.

Furthermore, soft soils are observed in sea shores and exhibi expansion from stream mouths to the valleys. They also can be seen interior sections locally. These mostly correspond to Sultanbeyi Formation and observed in plains and low altitude slopes.

## 8.3 Engineering Geology Map

Engineering geology maps are the main source for designing settlement convenience maps. All of the engineering risks within work site are identified in these maps.

Lithologies(sandstone, limestone, clay , gravel, etc.) which are common characters of formations that partakes in 1/2.000 scaled geology maps are used a base map in engineering geology map. In addition to this information, rock quality classifications, all field study and measurement locations with all of the soil risks determined in area (liquidization, mass movements, water overflow, karsting, etc.) are mapped areally without illusrating risk groups.

A sample of the engineering geology map that is prepared in 1/2.000 scale given in Figure 8.3.

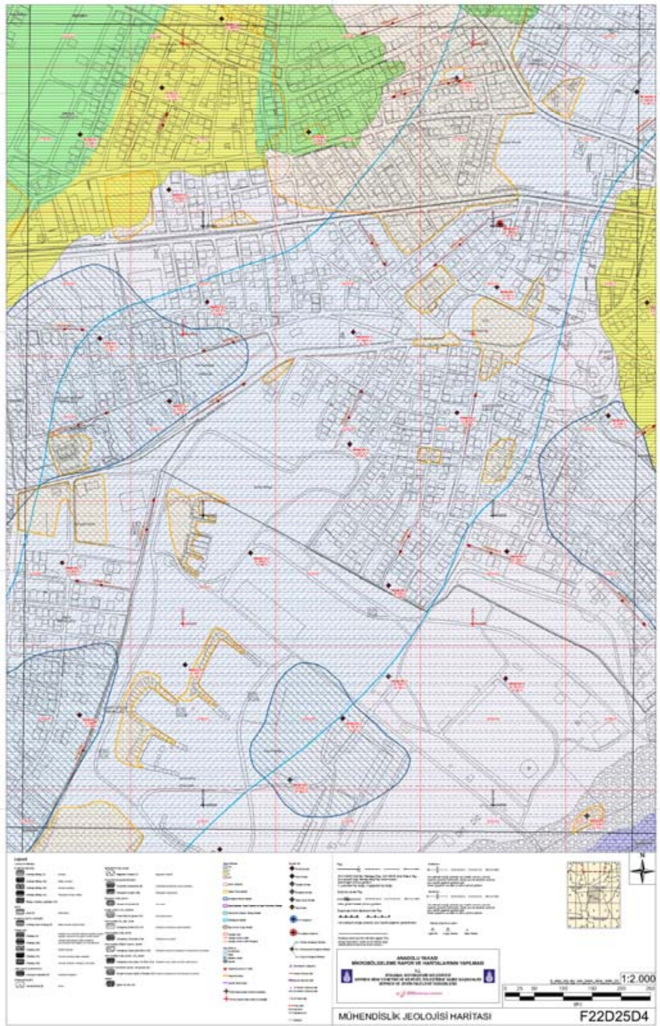



Figure 8.3 Engineering Geology Map (1/2000)

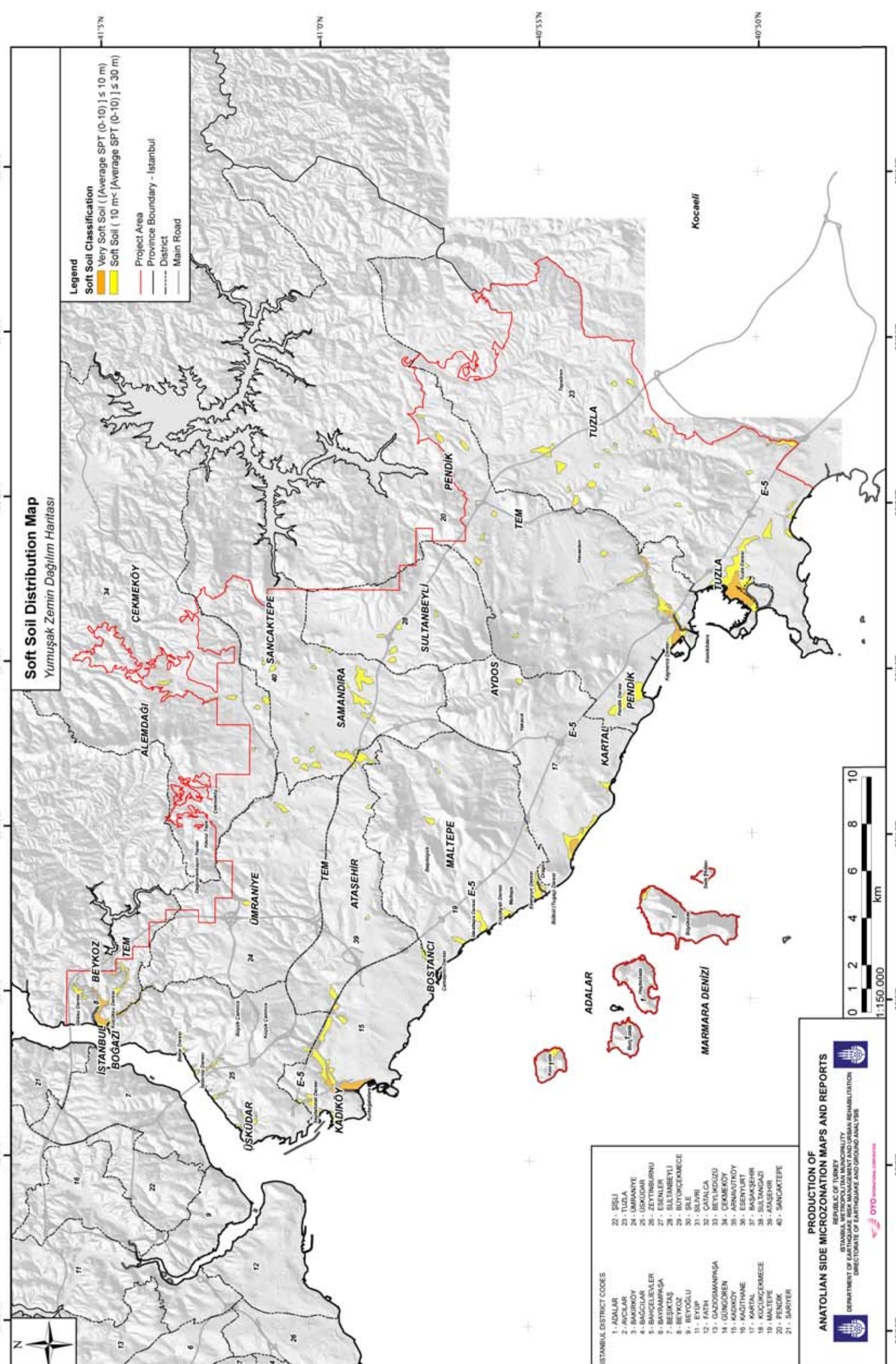


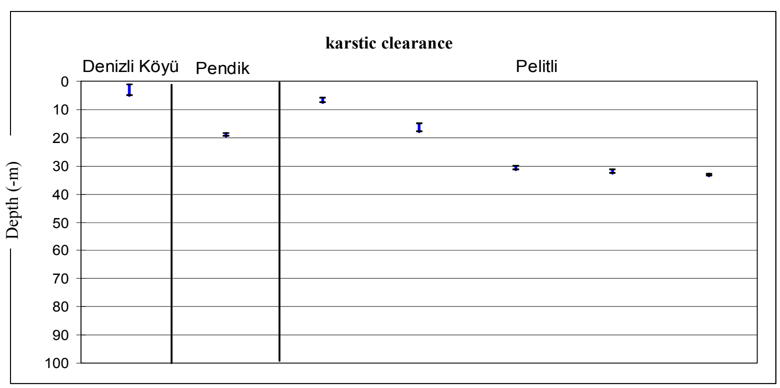

**Figure 8.4 Soft Soil Distribution Map**

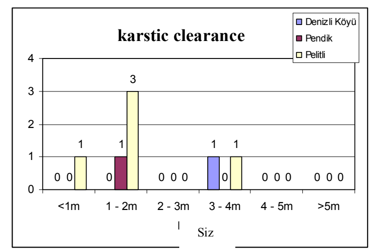
## 8.4 Karsting

Calcide, the main mineral that forms the limestone has a gradually melting property with water and it forms clearances which are also named as karstic clearances by going into the deeps of ground surface and melting with time. This clearances form a transition channel for waters coming from ground surface. Clearances expand depending on water condition and hydrolic slope with water's flow inside this channels. As a result of karst geographic formations in limesone distribution area some engineering problems such as subside, dolines may arise.

Inside research area in limestone distribution area at most of the borings applied clearances are detected and this clearances are filled with clay, silt, sand type materials named as karstic clearance fillings. For this reason subside danger is not expected. As a resut of boring studies, in Denizli village Formation, Pendik Formation and Pelitli Formation Limestones karstic clearance and clearance filling are observed.

**Chart 8.4 Depth Distributions of Karstic Clearances in Formations that involve Limestone**




| Formation | Number of data | Size (m) | |
|---|---|---|---|
| | | Min. | Maks. |
| Denizli Köyü | 1 | 3.7 | 3.7 |
| Pendik | 1 | 1 | 1 |
| Pelitli | 5 | 0.5 | 3 |

Most of the karstic clearance-fillings are seen in Pelitli Formation. Karstic clearance-fillings of Kartal Member of Pendik formation is at 20m deeps even if it is observed at 40m from place to place.

Thickness of karstic fillings are about 0-5m in Denizli Village Formation and Pendik Formation. Thickness in Pelitli Formation on the other hand varies between 5m to 10m. In all of the field karstic clearance size generally is not more than 4m.


**Figure 8.5 Core Chest ( Karstic clearance between 0 -6 m )**

Karstic clearances are also one of the most significant criteria for structure base type and base depth design. Therefore, karstic clearances observed in the field are mapped by classifying them according to problem depth conditions of more or less than 4 m and more than 10m.

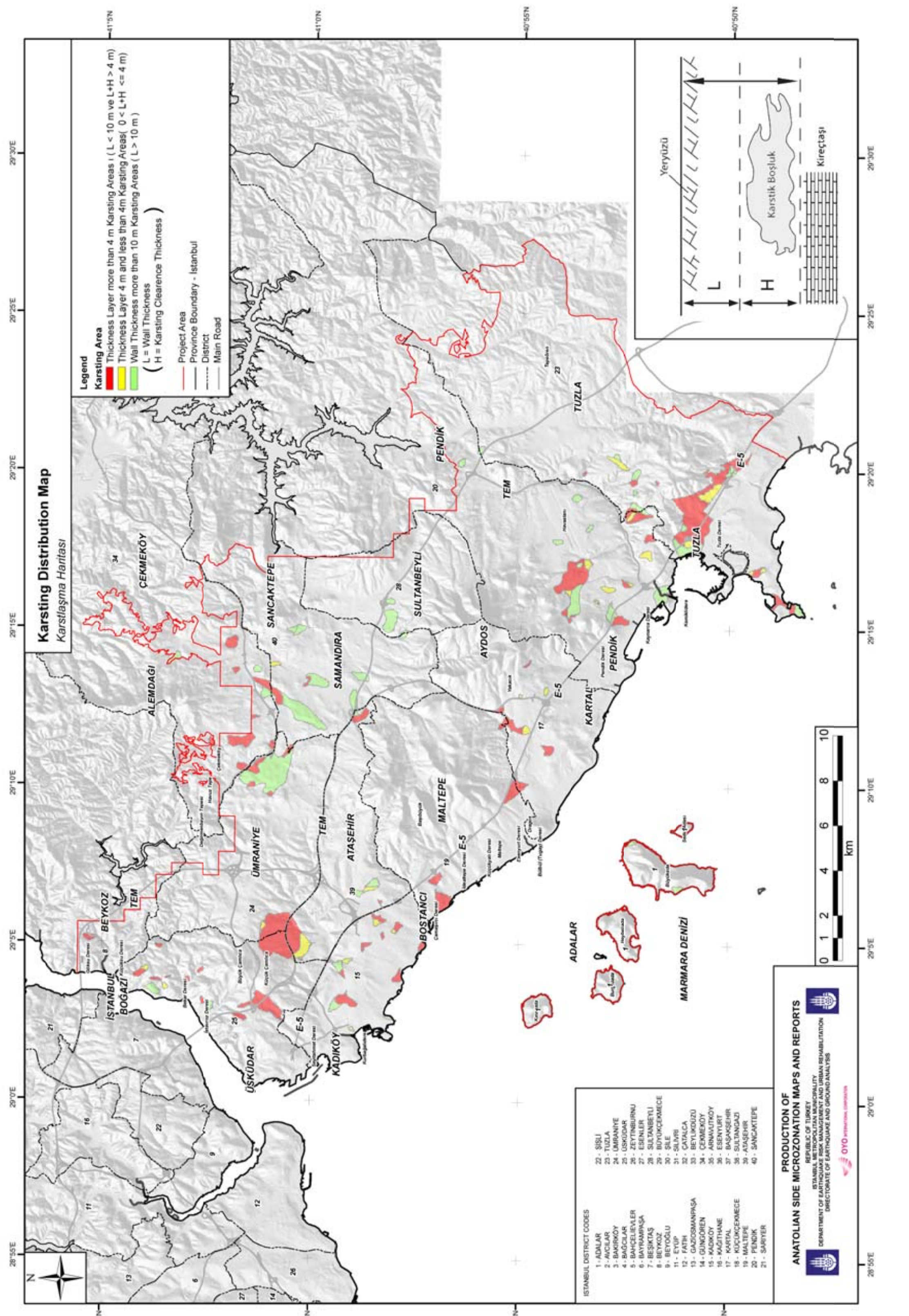



**Figure 8.6 Karsting Map**

### 8.5 Liquidization Danger

During an earthquake loose waterlogged sand/sandy soils loose volume as a result of temporory and continious loads effect and this increases clearance water pressure making soil slide resistance decrease. Such type of soils instantly pass into liquid state from solid state and this is called ‘‘liquidization’’. Big scaled settlement, bearing strength loss, slope falls, deformations occured in structure bases which all takes place in areas with soil liquidization bring about huge engineering problems.

The purpose of liquidization danger analysis is to idendify the areas that have the liquidization risk. Liquidization risk level is an important factor to determine the convenience of settlement of the areas within the Project site. For this purpose in determination of risky areas: Security Factor that is found by calculation of CSR(Cyclic Stress Ratio) and CRR (Rolling Resistance) is added along all of the risk depth and PL value is reached. As a result areas with more thatn 0 PL value are specified to be possessing liquidization potential.

**Chart 8.5 Liquidization Danger Criteria**

| Area | Criteria | Definition |
|---|---|---|
| $A_L$ | $P_L > 15$ | High Risk |
| $B_L$ | $5 \leq P_L \leq 15$ | Medium Risk |
| $C_L$ | $P_L < 5$ | Low Risk |

All of the stream beds fo project site connected with Bosphorus and Marmara Sea, shore fillings, Sancaktepe and Sultanbeyli district center sections, north of Tuzla district ( east of Sabiha Gökçen Airport) are detected to be on liquidization risk. Figure 8.7. These areas cover a total of 36.02 $km^2$ area and this amount corresponds to study field 7.07%.

Streams that have liquefiable layer with more than 10 m are: Göksu Brook, Küçüksu Brook, Seyitahmet Brook, Kurbağlı Brook, Esenyurt Brook, Tugay Brook, Kemiklidere Brook and Tuzla Brook.

Streams that have liquefiable layer with less than 10m: Bekar Brook, İstavroz Brook, Çamaşırcı Brook, İdealepe Brook, Küçükyalı Brook, Pendik Brook and Kaynarca Brook.

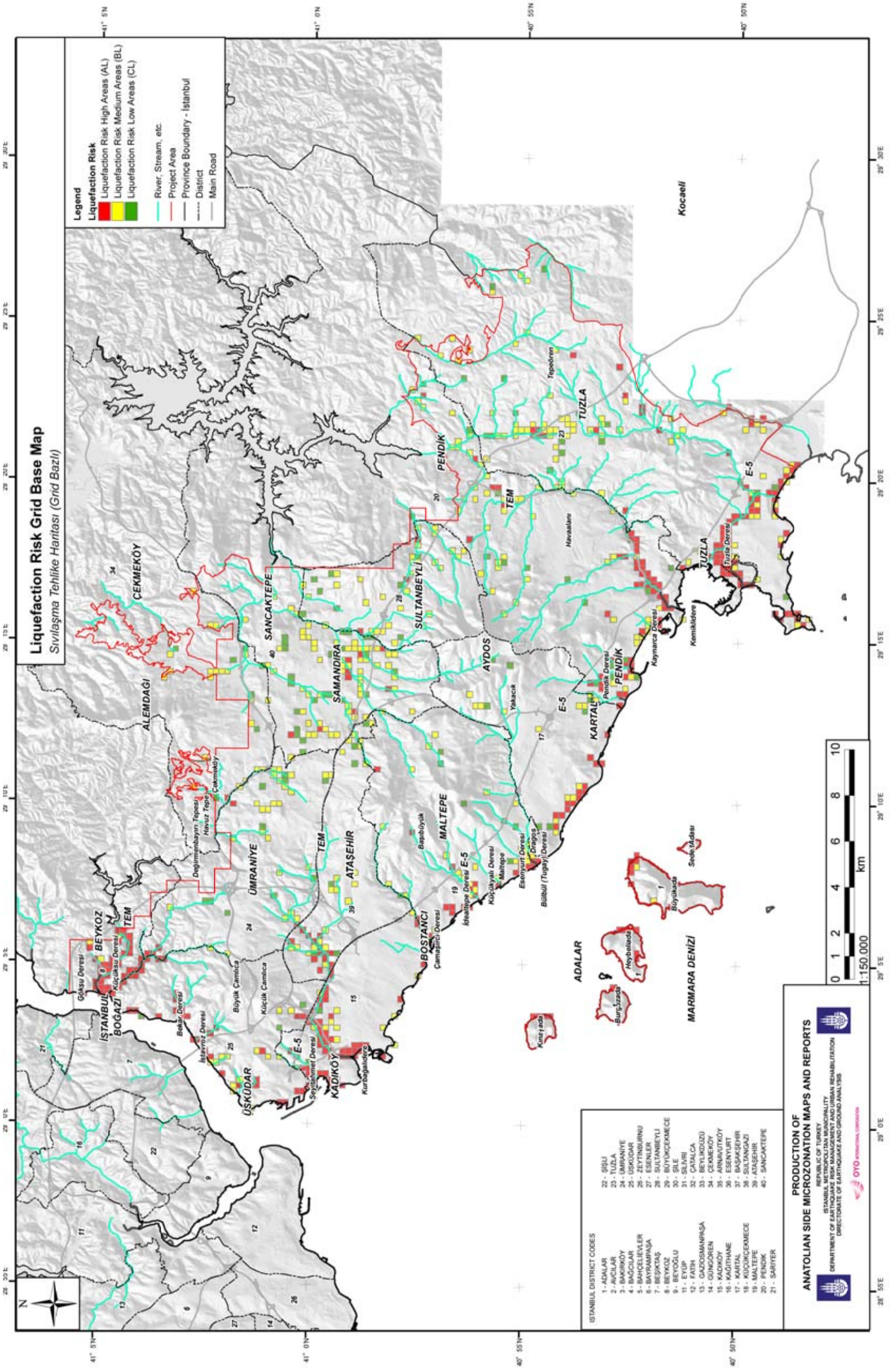



**Figure 8.7 Liquidization Risk Map**

Liquefiable layers observed in project site are Alluvium, Kuşdili Formation, Beach Talus and Artifical Fillings. Tertiary sediments like Sultanbeyli and Orhanlı are also evaluated as liquefiable altough they have comparatively less risk than anthropogene sediments. As it can ben understood from the Figure 8.8 below, while liquidization risks of lithologies belonging to soil environments is generally analysed, extremely weathered granite belonging to Sultanbeyli Formation and extremely weathered arcose unit belonging to Kurtköy Formation are also analysed.

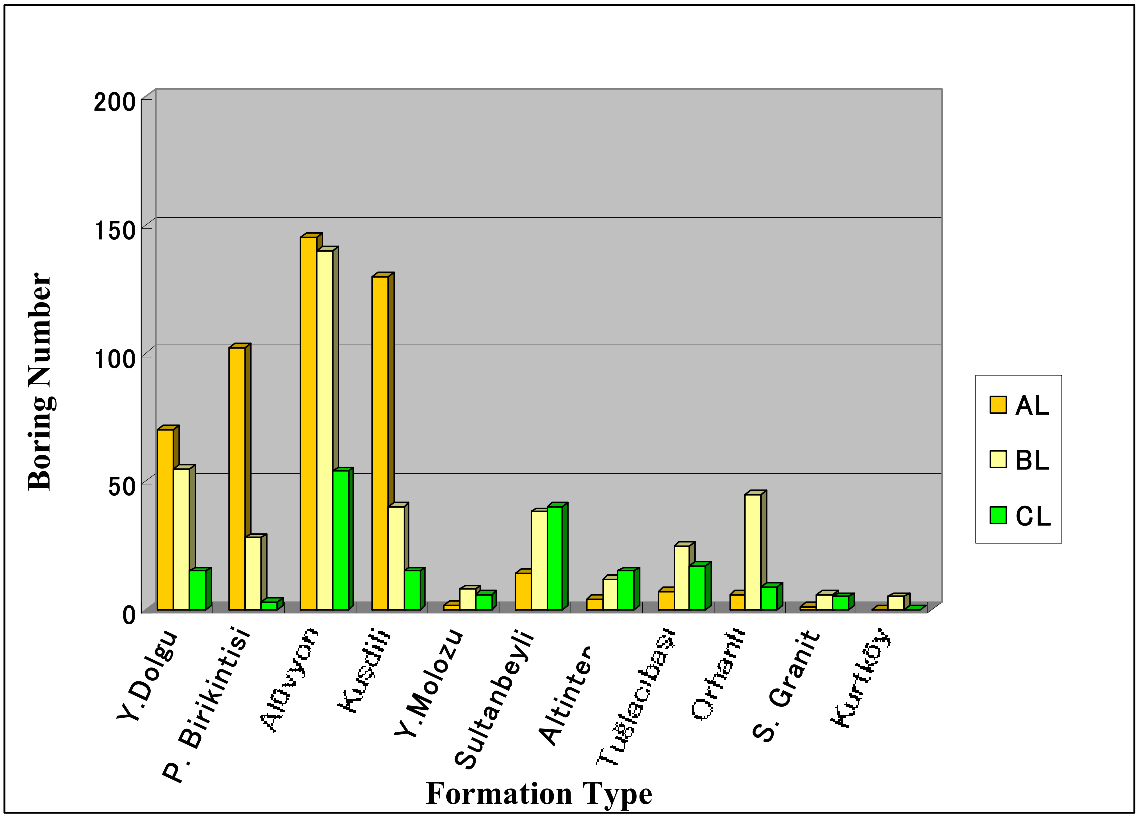



**Figure 8.8 Typical Liquefiable Formations**

Normally the settlement of 30cm is known to do no harm to the structure. As a result of these studies, places with AL liquidization level will havemore than 30cm settlements and special precautions should be taken in these areas. In such types of soils it is important to design structure bases in a way that they can withstand liquidization effects and makin soil enhancement.

Horizontal flor displacements that stems from liquidiation are calculated for typical spots and, this value for $A_L$ areas with high liquidization possibility is approximately 0.63m, for $B_L$ areas with medium liquidization possibility it is 0.31m. Furthermore soil settlement values that can result from liquidization in $A_L$ areas vary from 0.14m and 0.48m with an average of 0.27m. Soil settlement values for $B_L$ areas on the other hand vary from 0.03m – 0.16m with an average of 0.06m.

## 9. MASS MOVEMENTS

Any kind of mass movements either active or potential are aimed o be detected, analysed in detail and presented research results. For this purpose in addition to active stability problematic areas that are detected in 1/2000 scaled geologic mapping field studies, potential areas are tried to be specified by using slope stability analyses method (Siyahi & Ansal Method and SlopeW Method)

Stability problematic regions within the area are analysed by the subject headings presented in below figure (Figure 9.1)

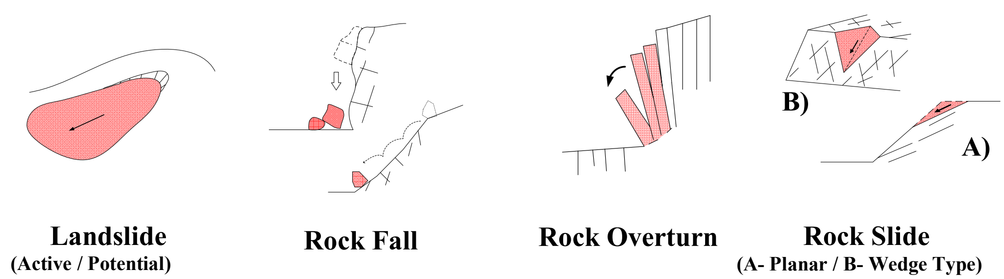



**Figure 9.1 Stability Problematic Area Types**

All stability problematic slopes form a surface of 17.15 $km^2$ and this ratio corresponds to study fields 3.36%.

### 9.1 Landslide

First and most effective step for reveal slopes that display landslide morphology is stereoscope study. Stereoskop interpretation is primarily used for revealing potential slopes in this Project. Moreover DEM database is used to utilize hill shade maps, satallite images and 1/2000 scaled topography maps. With this study typical lanslide characteristic prensenting slopes(Active/Potential) which are active or now stable though formerly active are found.(Figure 9.2) In this detected areas landslide presence is examined by doing primar field studies. As a result of these examinations on areas that thought to have active and potential lanslide risk are applied and planned instrumental field studies(boring, geophysics methods, laboratory). As a result of dense flora and tough field conditions in 9 out of 26 detailed study planned area can not be done. In order to analyse the data obtained by detailed field study, GEO-SLOPE International, Ltd. Kanada's SLOPE/W version 7.14 software (Morgenstern-Price Method) is used and areas are evaluated for both earthquake and non-earthquake conditions.

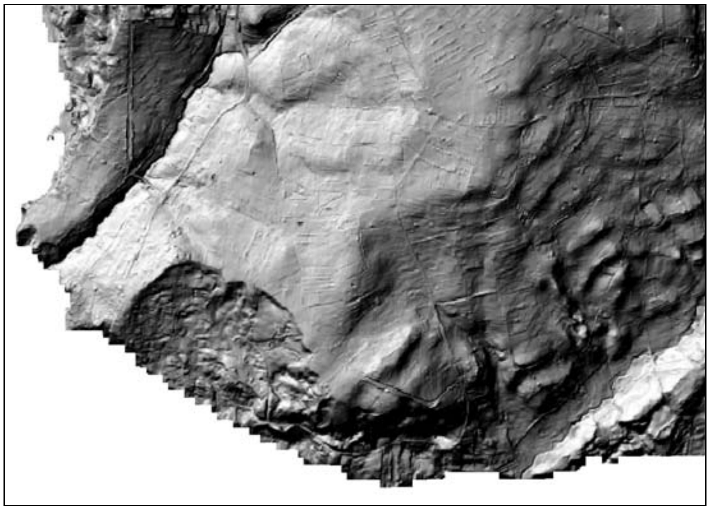


**Figure 9.2 Landslide Area's 3D DEM Data Detection**

Risk levels of the areas that are analysed in detail are evaluated according to the classification given in Chart 9.1. As a result of this detailed anayses in 26 fields, 16 are in $A_{SL}$, 7 are in $B_{SL}$ , 3 are in $C_{SL}$ risk groups. For the evaluations Security Factor (Fs) calculated for seismic condition is used. Distribution of potential Landslide areas are shown in figure 9.3. Distribution graphic of geologic formations corresponding to the risk levels specified a result of analyses results are given in Figure 9.4.

**Chart 9.1 Danger Risk and Field Convenience Level Classification**

| Landslide Condition | Risk Level |
|---|---|
| Landslide with less than 1.0 Security factor in case of earthquake (Fs<1.0) | **$A_{SL}$**<br>Possibility of collapse of structures or facilities on the slope because of big movements in case of an earthquake. |
| Landslide with security factor between 1.0 and 1.5 in case of an earthquake. (1.0<=Fs<=1.5) | **$B_{SL}$**<br>Crack and bending possibility of structures or facilities on the slope as a result of landslide in case of an earthquake. |
| Landslide wih more than 1.5 security factor in case of an earthquake (Fs>1.5) | **$C_{SL}$**<br>Possibility of crack and some deformations in structures or facilities on the slope as a result of lackness in soil endurance because of landslide activity in case of an earthquake. |

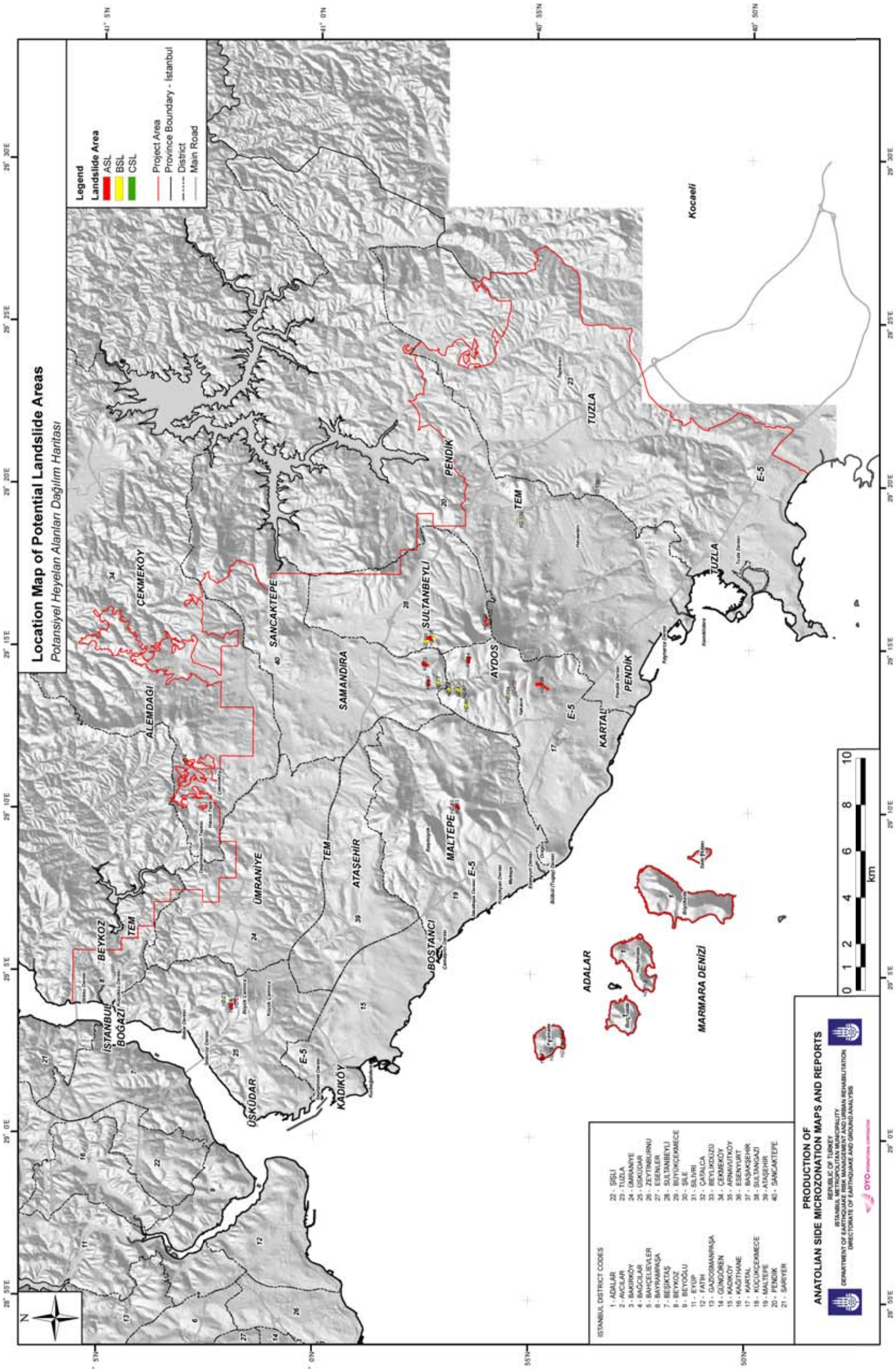



**Figure 9.3 Potential Landslide Areas Distribution Map**

According to the information obtained from analyses, Talus, Kurtköy and Sultanbeyli Formations are more prone to landslide potentially. Other geologic formations potential for landslide is less and not that much risky.

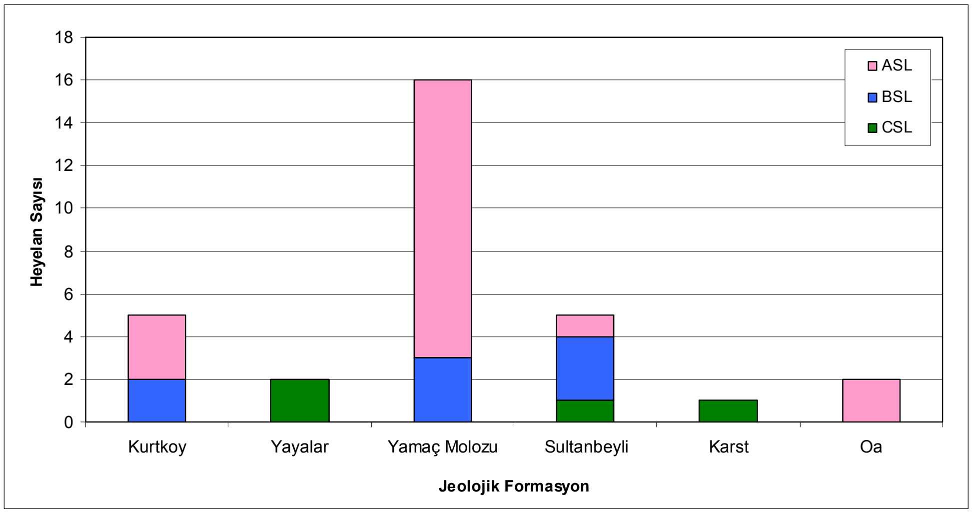



**Figure 9.4 Landslide Area Number of Formations**

During the detection of Landslide risk, analyses in direction of grid base slope stability research are also made. These analyses are mostly in purpose of detecting a potential landslide in a given magnitude of an earthquake. Two methods are pursued at this phase. First is Siyahi & Ansal,1999 method. This method can only make slope stability analysis in earthquake conditions. Second method is the analysis type which is done by the utilization of Slope/W (Moergenstern-Price) and Arcmap softwares. In both analysis methods detecting the stability of grids is done by GIS softwares and separation of the fields into 10 x 10 dimensional grids. Security factor of slope stability on each grid is calculated. Potential areas selected by the calculations are observed to be in convenience with the actual field conditions during later field studies. Areas that are detected to be potential slope by Slope/W software reveal wider expansions than the ones detected by Siyahi & Ansal method. So in order to be more dependable both areas obtained by Siyahi & Ansal Formula and Slope/W software are made a unified single product.

The fact that stability problematic areas' being developed on talus of Aydos Formation which have higher incline of slope is supported by analyses. Therefore most of landslide areas take place in slopes inside Aydos forest where there is no habitation.

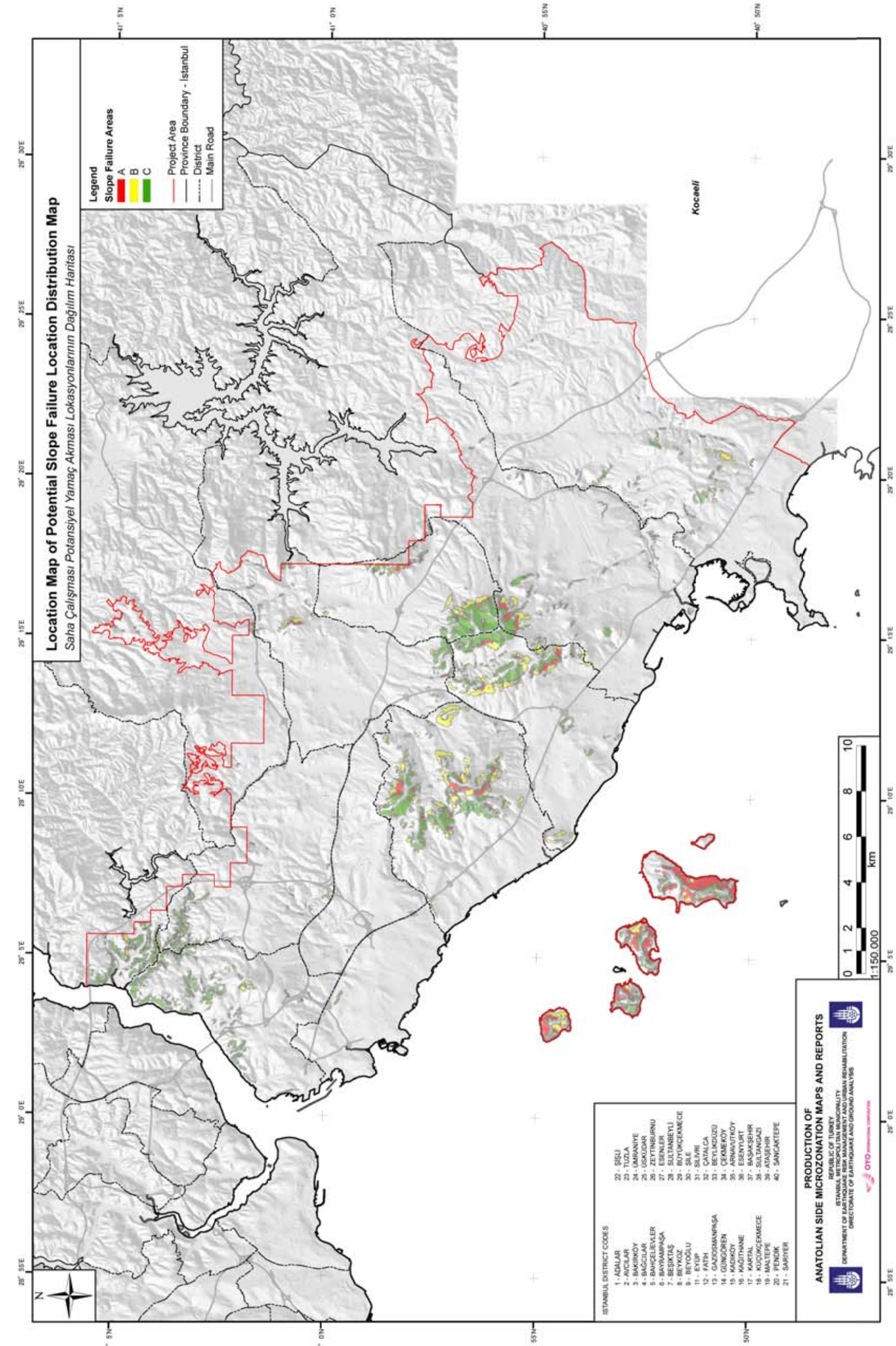



**Figure 9.5 Potential Slope Stability Problematic Areas**

## 9.2 Kaya Şevi Duraysızlığı Rock Slope Unstability

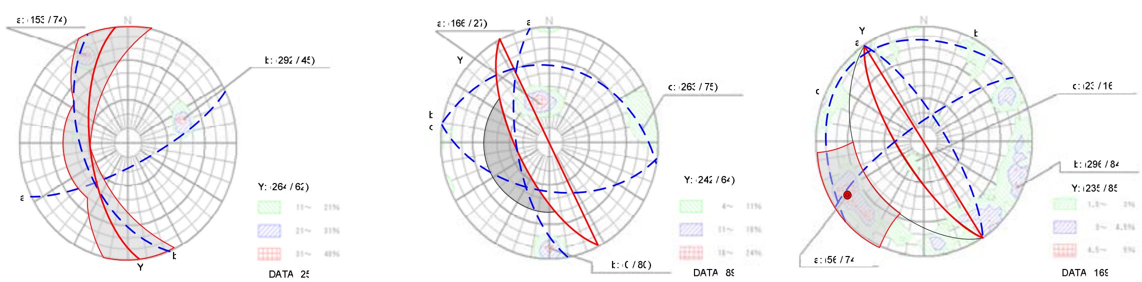
Areas studies in rock slope unstability are divided into 3 groups according to stability and rock collapse. These are Rock Fall, Toppling failure and Rock Slide.

During the field studies done within the scope of microzonation study, layer, joint and incline directions are measured as far as the surfacings enable from naural and artificial mostras belonging to different formations. Layer-joint directions measured in each formation and incline directions are drawn in Schmitt Net and dominant directions of layers and joints are found.

2m of cells with direction and incline angle information are created in GIS software depending on DEM data. GIS analysis is used to select the cells with more vertical slope incline and with direction within the change gap previously detected. Slopes that has not much unweathered rock or defined as mostra by geologic researches in selected cell areas are selected as potential slope. Detailed field research is conducted on this slopes. It is confirmed that areas revealed by analysis method are in convenient with actual field conditions.

As a result of these studies rock slopes are divided into 3 types as of Rock Fall, Toppling Failure and Rock Slide. Risk condition is detected in every slope evaluated as Rock Slide and Toppling Failure by using Kinematic analysis method. Rock fall on the other hand is detected by field observations.

Sample Kinemaic anaysis result is given in Figure 9.6.



**Rock Slide (Planar)** | **Rock Slide (Wedge Type)** | **Toppling failure**

**Figure 9.6 Kinematic Analysis sample**

Blue lines displays joint’s doinant behaviour, while red line shows slope direction and incline. Grey section in the diagram shows the dangerous area. Danger area is defined by joints inside friction angle. If blue lines intersect at grey area it means that slope has a slide potential.

### 9.3 Rock Fall

According to the field research conducted on selected slopes, slopes where unstable rocks partake are evaluated as potential rock fall slopes. A total of 5 rock fall slopes are examined in Project site. In order to evaluate the danger unstable rocks on slope and slope condition are controlled.

**Figure 9.7 Rock Fall**

According to the results of the study, unstable rocks are found in quartzite and limesone areas. Generally it can be accepted that weathered sections are rare and these rocks are developed in a cracky area. Therefore quartzite and limestone areas have a higher rock fall potential compared to other geologic environments.

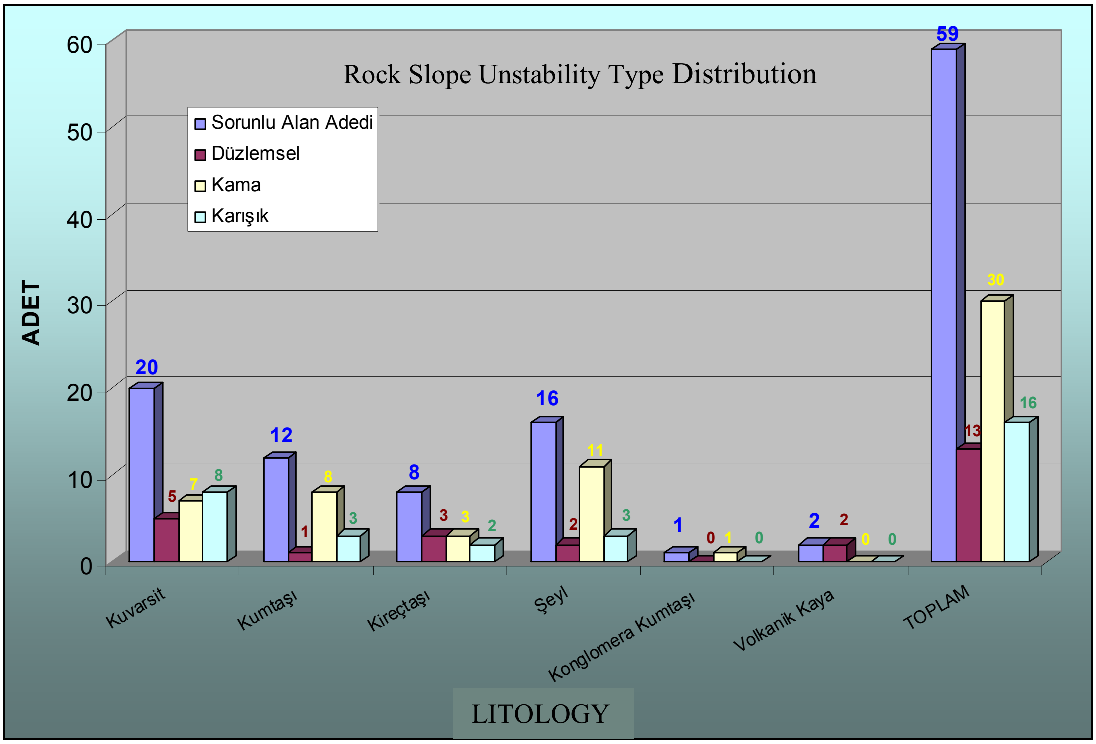
## 9.4 Rock Slide

According to the field research on selected slopes, slopes in unstable condition because of open cracks are evaluated as potential slope in terms of Rock slide unstability. 59 slopes are detected in Project site belonging to Rock slide unstability. By Kinematic analysis potential of these slopes is evaluated. Kinematic analysis is made by using ele. kelm data measured in each of slopes that have rock slide unstability potential. By this method planar and wedge shape rock slide potential is evaluated. As a result of the analysis made on 59 slopes: 30 of them have wedge type, 13 of them have planar and 16 of them have both wedge and planar slide risks. Therefore quarzite and shale lithologies have more stability problems than other lithologies and the density of wedge type and mixed (both wedge and planar) slide types in them shows that shear type deformation is widespread.(Chart 9.2). This result also match up with area's tectonics and structural geology studies.


**Wedge type slide** **Planar Slide**

**Figure 9.8 Rock Slide**

**Chart 9.2 Rock Slope Unstability Type Distribution**




## 9.5 Toppling Failure

According to the field researches conducted on selected slopes, slopes that are in unstable condition because of vertically open cracks are evaluaed as potential toppling unstability slopes and subjected to Kinematic analysis. As a result of Kinematic analysis 13 Toppling Failure Potential areas are detected.

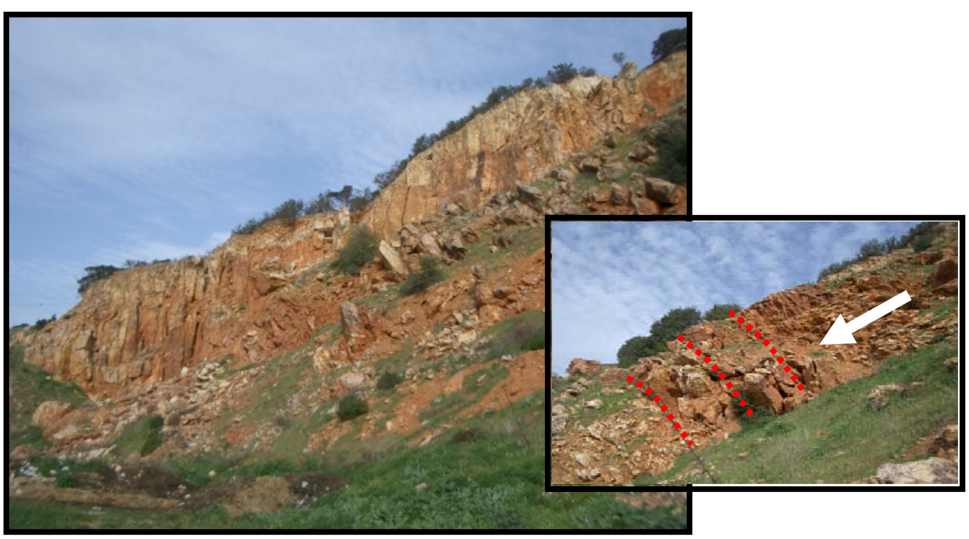


**Figure 9.9 Toppling on Slope**

According to the result of the study potential slopes are detected in shore areas that are observed as rocky places. Areas that exhibi hig angled joint progress can be thought to become as a result of geographic features or artificial work such as quarryies. Therefore areas forming rocky places or used for quarries (mine, stone etc.) should be take into consideration as potential toppling unstability areas.

Potential Rock Slide/Toppling numbers are given in Figure 9.10.

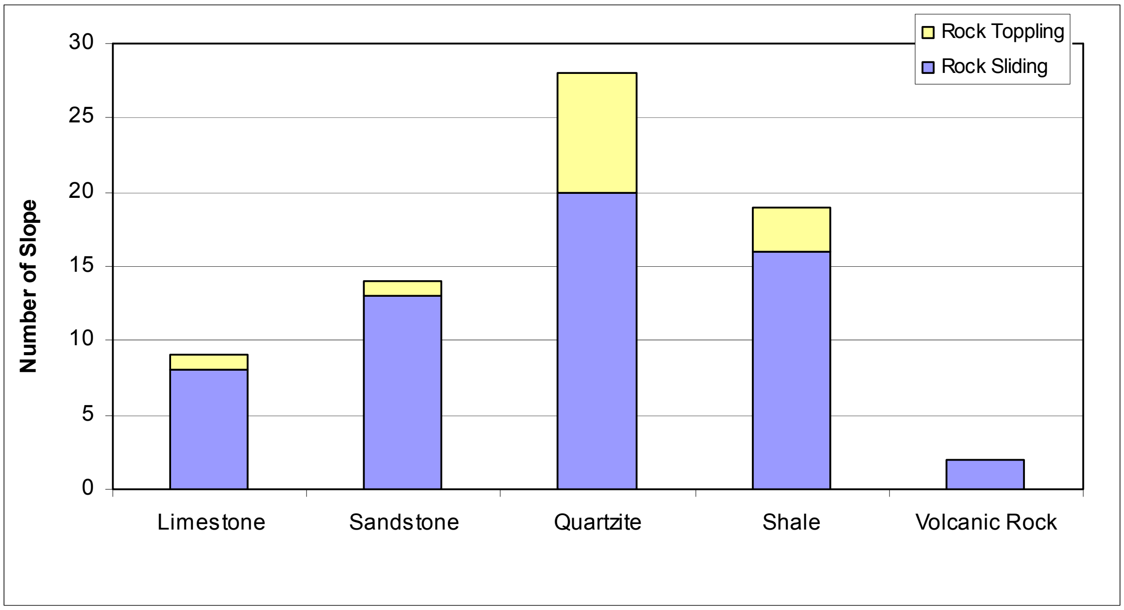



**Figure 9.10 Potential Rock Slide/Toppling Graphic According to Lithology and Numbers**

According to the figure above, highest Toppling Failure risks are again in slopes formed by Quartzite units which have the highest Rock Slide Risk as well. Potential rock unstability slopes' locations are given in Figure 9.11.

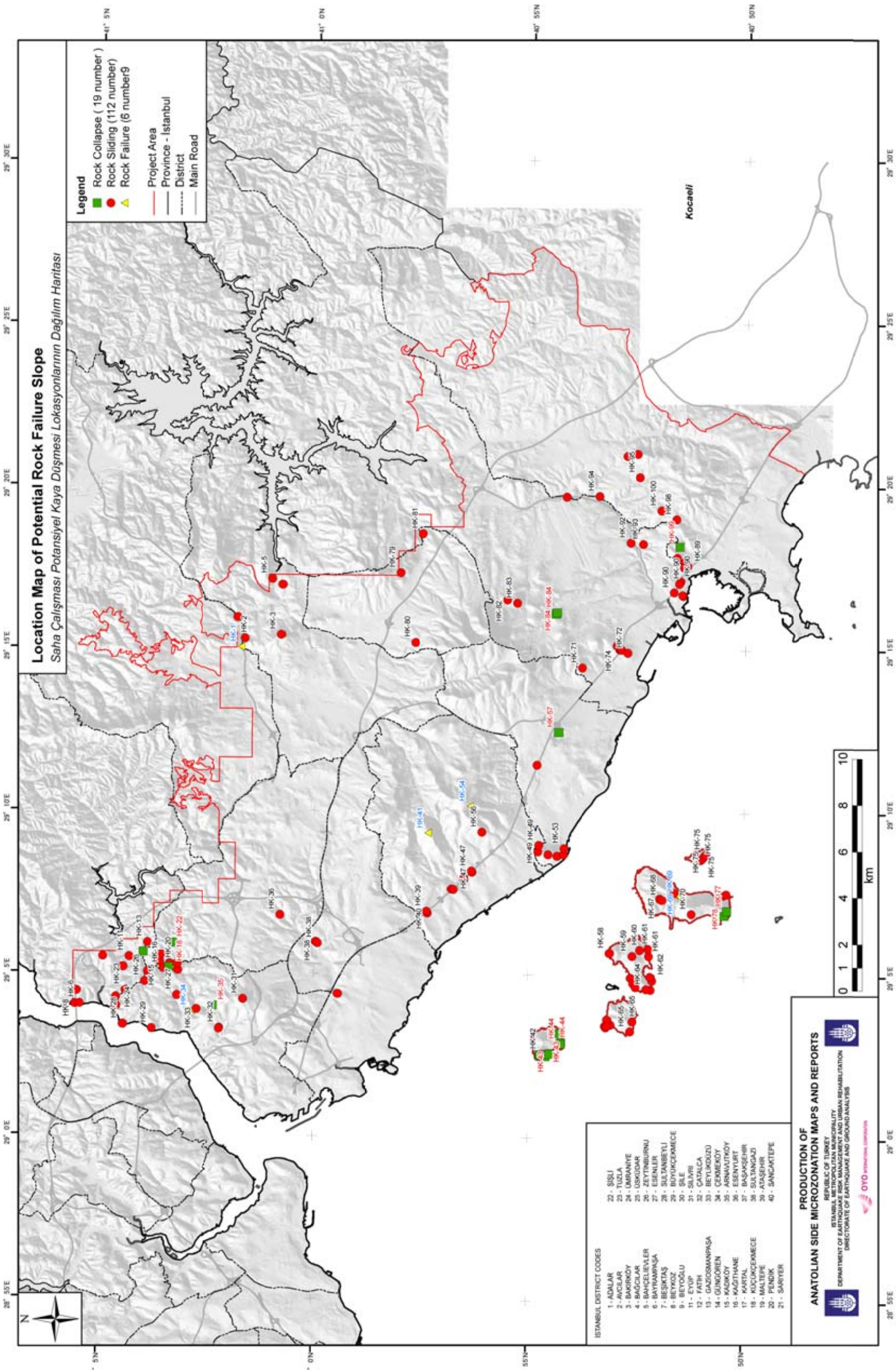



**Figure 9.11 Potential Rock Slope Unstability Distribution Map**

# 10. FLOODİNG RİSK

Analysis of the flooding of area within Project site depending on excessive precipitation, earthquake origin dam damage and tsunami effect are amde and ''Flooding Risk'' map is prepared. In the analyses of flooding based on Tsunami (relapse waves), Tsunami map data which is prepared for all of the Isanbul sea shore within the scope of the European Side-South Microzonation study is used.

In order to make the analyses posibble, precipitation data, flooding records, topography datas about related stream sizes drainage sysem data, dam sizes etc. information is gathered and data are prepared for analyses in digital environment.

## 10.1 Flooding Model As a Result of Ecessive Precipitation

In the first phase of the analysis, all project side is divided into small basin areas that possess drainage or own independent stream network system. This division process is made by considering topographic properties and drainage network distribution. Figure 10.1

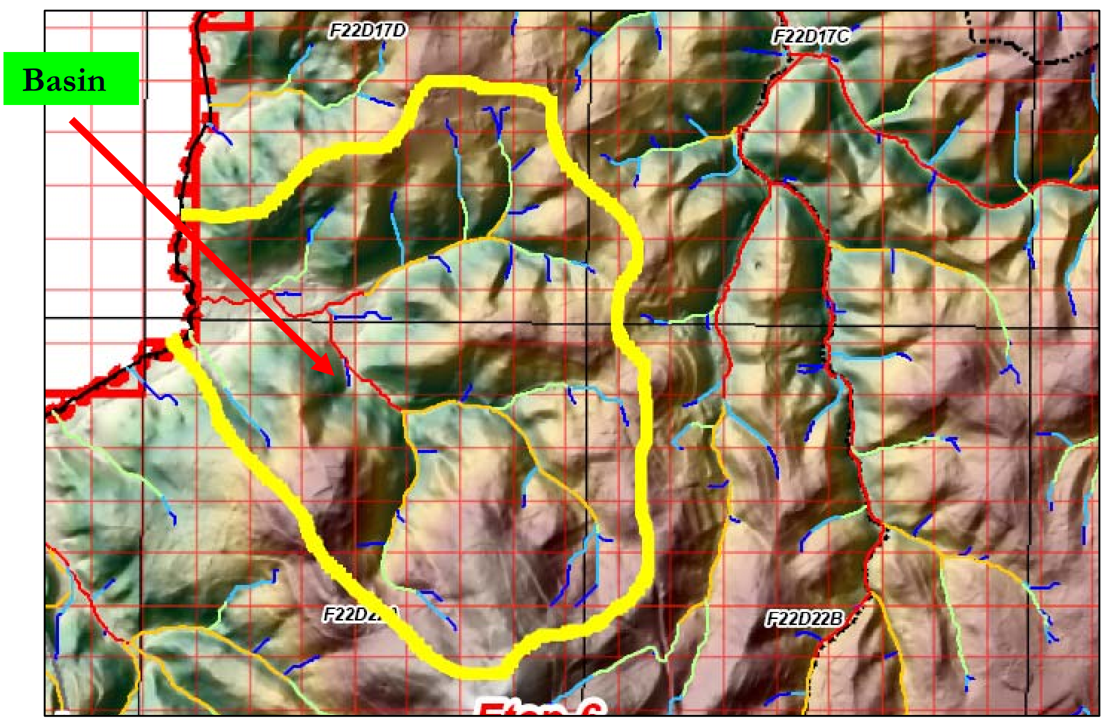



**Figure 10.1 Detection of Basin Areas**

Original digital altitude model (DEM) of all of the Project site is made into grid forms of 10mx10m and collapse areas are automatically selected by GIS(ArcMap) computer program. Figure 10.2

**Figure 10.2 Sample collapse areas**

Later basin area of each basin is calculated. Basin area is calculated by multiplying rain water volume (A) and basin area rain water depth(taken as 80mm). Drainage capacity of the basin (B) is calculated from total brook and drainage network lenght(Drainage Networks and data is provided by İSKİ). The penetration of rain water into the underground (C) is taken as ground's typical permeability.

Then, excessive water flooding amount(D) is calculated by [D = A – (B + C)].

Excessive rain water amount's (D) being less than 0 means that the basin has adequate water bearing capacity. It can be predicted there is no water flooding possibilty in these areas. On the other hand excessive rain water amount's being more than 0 means that the basin area can be subject to water flooding possibly in other words there is a potential of water flooding.

As a result of the analyses conducted based on basin, 10 basin areas are selected to have water flooding potential. In the second step of the analysis on these 10 selected areas WEP Model (Water and Energy transfer Process Model) that is developed by Japan Public Works Research Institute is used for advanced analysis.

Shematic illustration of WEP Model can be seen in Figure 10.3. Basin to be analysed is divided into grids of 10mx10m dimensions, penetration and exit of the water in each grid is calculated and summarized for all of the grids. During the calculations made by the program, Geologic conditions, Field usage conditions, permeable layer thickness, smoothness coefficient and permeability values are used.

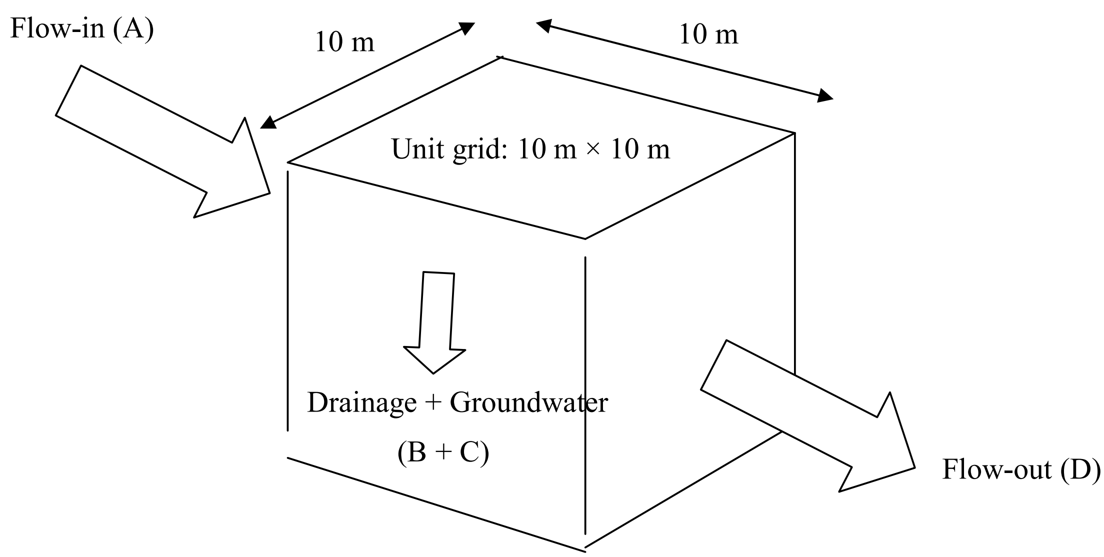



**Figure 10.3 Rain water flooding analysis calculation model**

Rain water model to be used in the analysis is as shown in the Chart 10.1.

**Chart 10.1 Analysis Rain Water Model**

| Current rainwater record | Rain water model for analysis |
|---|---|
| **80 mm / day**<br>Highest value recorded in Anatolian side meteorology stations since 2001: Elmali station, 2004.10.7) | **80 mm / hour**<br>(=worst-case scenario) |

Analysis results can be summarized as follows:

a) For every basin in analysis area some thin lines are observed according to beginning phase (T=0.1 hour) anaysis models. These lines are brooks and drainge lines with natural flow.

b) Beginning of the rainfall in flooding areas area identified as yellow – orange colors (T=0.1 hour). Water depth increases in many water lines.

c) Yellow color means water depth is in between 1 – 2m, orange color means that water depth is in beween 2 – 3m. No areas are detected with water depth of more than 3m.

d) Flooding areas match up with collapse areas selected in 1.phase analysis.

e) Maximum water depth is reached after 1.2 – 3.6 hours from the start of the rainfall depending on area size and soil conditions( topographic, geologic and field usage conditions)

f) After 6.0 – 8.0 hours from the start of the rainfall water deph in all areas return back to beginning phase (T = 0.1 hour) level. (Figure 10.4)

**<Beginning Water Depth Before Flodding><Maximum Water Depth After Flooding>**

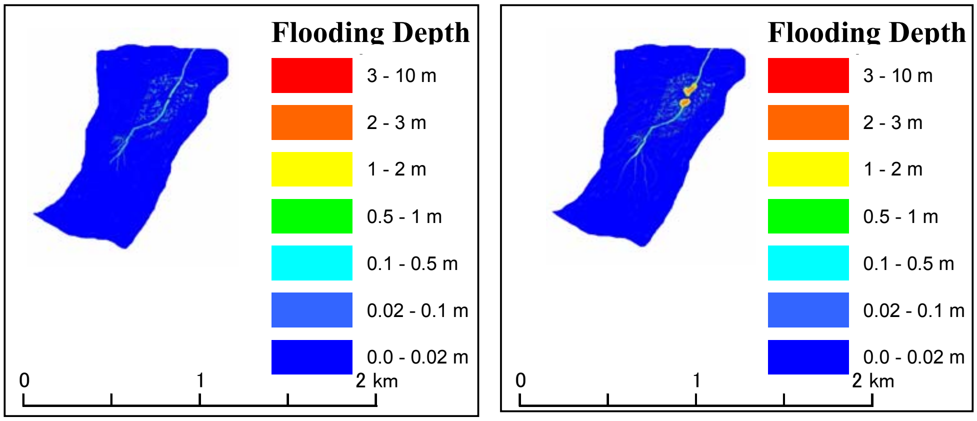
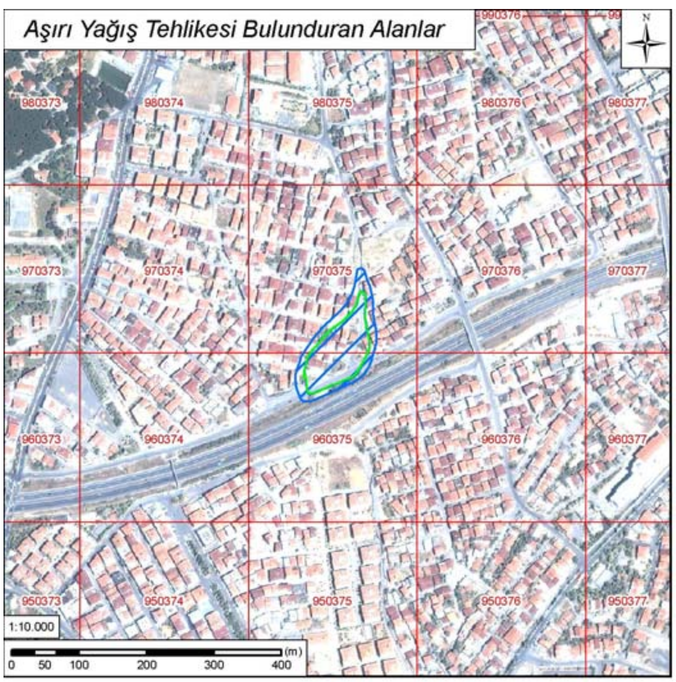



**Figure 10.4 Flooding area Detected as a result of the Analysis ( Flooding Depth)**

In floodings as a result of excessive precipitation, water flooding depth analysed is 1-2 meters average and maximum flooding depth is 2.6 meters. In Figure 10.5 satellite images of flooding sample area analysed and detected risky is given.

All of the detected areas as results of analyses and flooding results are given in Chart 10.2.




Number: 8-3

Place: Üsküdar District, Bulgurlu Street, O-4 road direction north side (O-4 north side street)

Flood Area:

Aprox. 15,400 $m^2$

Flooding Amount:

Aprox. 20,000 $m^3$

Highest Water Depth:

Aprox. 2.2 m

**Figure 10.5 Potential Flooding Area Because of Rain Water No.8-3**

**Chart 10.2 Areas Detected to be Risky and Flood Results**

| No | Adress | Flood Area ($m^2$) | Flooding amount ($m^3$) | Highest Water Depth (m) |
|---|---|---|---|---|
| 8-3 | Üsküdar District, Bulgurlu Street, O-4 road direction north side (O-4 north side street) | 15,400 | 20,000 | 2.2 |
| 8-4 | Ümraniye District, Namık Kemal Street, O-4 raod direction north side | 25,600 | 35,800 | 2.4 |
| 23-5 | Ataşehir District, Ferhatpaşa Street, E-80 road direction south side (E-80 side street) | 18,900 | 24,600 | 2.3 |
| 23-6 | Ataşehir District, Ferhatpaşa Street, E-80 road direction south side (E-80 side street) | 50,500 | 65,700 | 2.1 |
| 24-3 | Sancaktepe District, Kemar Türkler Street, Mimar Sinan Bulvarı direction | 75,300 | 90,400 | 2.6 |
| 24-5 (north side) | Sancaktepe District, Eyüp Sultan Street, E-80 road direction (near Yakacıl Caddesi) | 70,200 | 77,200 | 2.5 |
| 24-5 (south side) | Maltepe District, Büyükbakkalköy Street, near Samandıra Kartal Bağlantı road | 19,400 | 21,300 | 2.3 |
| 24-6 | Sultanbeyli District, Hasanpaşa Street, E-80 road direction | 80,900 | 97,100 | 2.2 |
| 24-8 | Sultanbeyli District, Hamidiye Street, E-80 raod direction (near Fatih Caddesi) | 22,000 | 28,600 | 2.2 |
| 25-3 | Pendik District, Harmandere Street, E-80 road direction (near Kurtköy Road) | 46,800 | 51,500 | 2.3 |

## 10.2 Flooding Model Depending on Dam Damage

Dams that can affect inside the Project side are determined by analysing dam distribution map provided by DSİ. The only dam that can affect Project site is Elmalı II Dam. Effects that can happen as a result of an earthquake on the Elmalı II Dam are analysed and results of this analysis is shown as maximum depth map, maximum flow speed map and arrival time map.

**Elmalı II Dam**

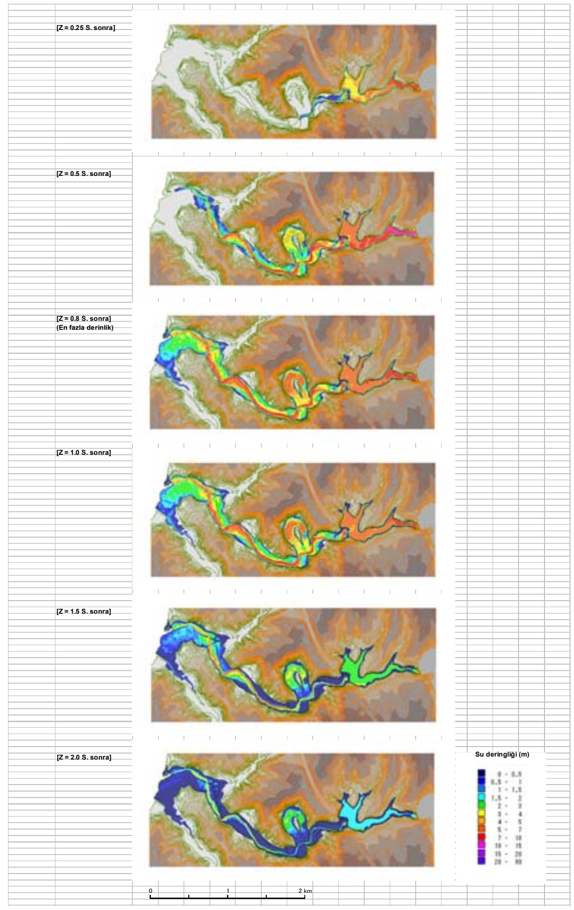



**Figure 10.6 Water Depth Time Map**

In case of a possible damage, 10 – 15m maximum depth is detected in the upper parts of stream that takes place in front of dam body. In the edge areas of the stream almost all of the maximum depth is less than 10 m. Along the upper areas of the stream 10-15 m/sec maximum flow rate is specified. Maximum flow speed in stream's edge areas are observed to be less than 10 m/sec. Water flow arrival time which occur because of the dam damage is approximately 10 minutes under highway bridge (TEM Molla Gürani Viaduct), and is approximately 40 minutes in sea shore (The area where Göksu Brook unifies with Bosphorus)

Flooding stemming from dam damage is thought to be as the worst case scenario and its possibility of occurence is very low.

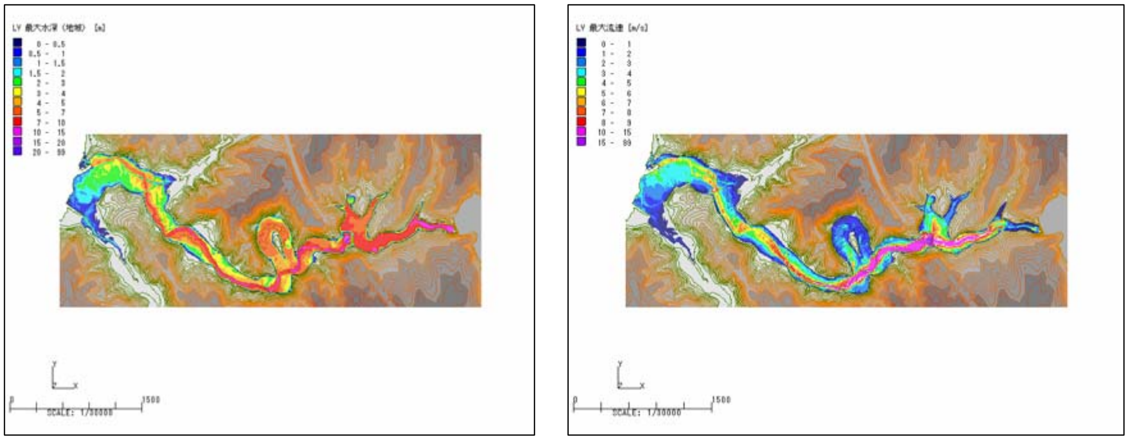


**Figure 10.7 Depth and Flow Speed Maps**

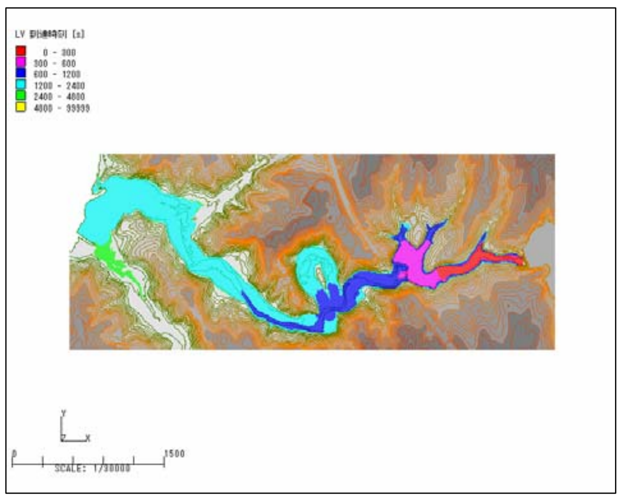


**Figure 10.8 Arrival Time Map**

### 10.3 Flooding Model Depending on Tsunami (Relapse Waves)

According to the results of the tsunami analysis prepared within the scope of European Side (South) Microzoantion Project, tsunami wave altitude that occurs in the land and also covers Anatoloian Side Project site is generally lower than 3 m. Nevertheless only the tsunami wave altitude detected in sea shore of the Kartal region in a small area is a little bit more than 3m.

It has been calculated that waves occured because of Tsunami effect can only penetrate maximum of 1000m (Tuzla Abduş Lake)inside sections. As a result tsunami waves can not progress into the South directional abrubt slopes of the islands. Tsunami waves characteristically exhibits expansion towards shore filling areas mostly and these areas are Kadıköy Moda, Kurbağlıdere, Bostancı, Kartal, Maltepe, Tuzla, Pendik sea shores, Tuzla Abduşlake and around them.

## 10.4 Flooding Danger Map

Key factors when preparing ‘‘Flooding Danger Map’’ which occur as a result of excessive precipitation and tsunami are water level and wave altitude.

The relationship between tsunami wave altitude and the damage on the structures is a widely studied topic among various researchers. To summarize these studies, below mentioned connections can be used between physical damaes of he structures and tsunami wae altitude:

- Wave altitude < 0.5 m : Undamaged or low damage
- 0.5 m ≤ Wave altitude < 3 m: Damage may be seen in frame houses
- Wave altitude ≥ 3 m : Damage and destruction may be seen in ferroconcrete and loadbearing buildings

There is no such connection for flooding danger because of exessive precipiation. In other words it is more imporant to idenify the risk areas instead of risk levels in the analysis of flooding danger.

According to the technical specificaitions flooding danger because of excessive precipitation is defined as shown in Chart 10.3

**Chart 10.3 Flooding Risk Classification**

| Area | Definition | Criteria |
|---|---|---|
| AF | High risk | Areas with Tsunami or flooding potential |
| CF | Low risk or no risk | Areas with no Tsunami or flooding potential |

AF areas(Figure 10.9) are located on the areas as follows in Project site :

- 10 areas in study fields middle sections generally around Tem and E5 highways (Flooding because of excessive precipitation)
- In down flow area of Elmalı Dam along the stream bed between TEM Molla Gürani Viaduct and Göksu stream bosphurus connection ( Flooding becausr of Dam damage
- Along all of the Marmara Sea and Bosphorus sea shore (Flooding because of Tsunami)

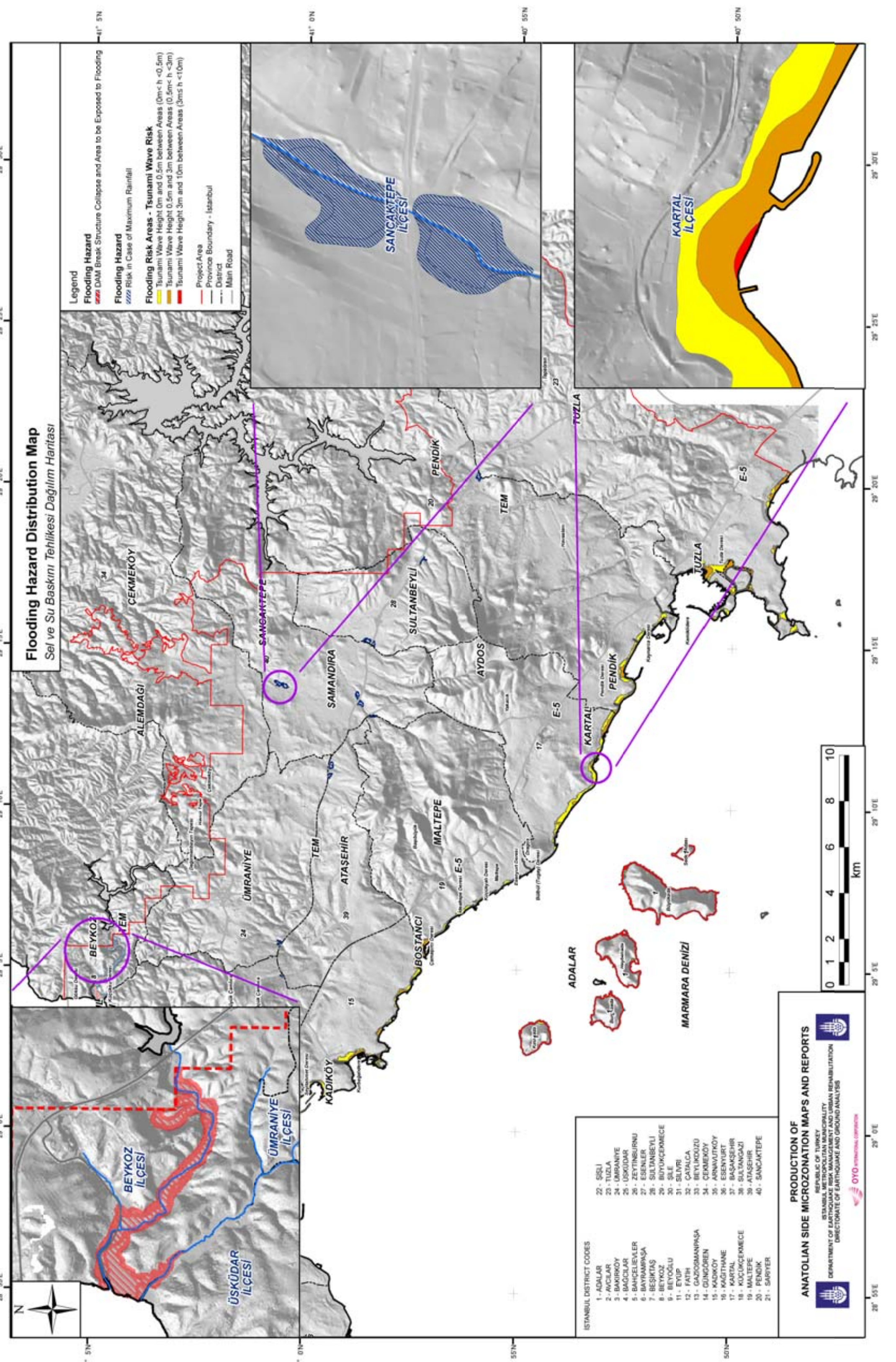



**Figure 10.9 Flooding Risk Distribuion Map**

## 11. ARTIFICIAL FILLINGS

According to the international standarts, building of the sructures on artifical fillings creates big problems in terms of base and structure engineering. Identifying material type and properties of filling field expansions is extremely significant to eliminate such problems and determination of convenient planning criteria for proper structuring.

There has been 4 different studies made without a pre-condition in order to identify expansions of any kind of artifical filling fields partaking in the Project site and in direction of specifying their material type and thickness to examine structuring conditions. These are:

A. Data and maps belonging to artificial filling fields detected before the microzonation study are collected and digitized.

B. Former Air photos and digital topographic data is used to detect the places and limits of old stone and sand quarries and quarry limits that are found are digitized. During this process filled quarry areas are deected and studied.

C. Topographic data produced from 1987, 1999, 2004 and 2007 at present maps are superposed in digital environment and places that exhibit topographic differences ( filled by filling) are tried to be detected and limits obtained area digitized.

D. Filling areas detected during field studies are digitized by drawing on related sections.

In 55% of borings done in the area various thickness of artificial filling material are cut. The corelation and mapping of these different thickness filling cut in borings of densely populated regions in particular is impossible. Besides lots of artificial filling material with less than 3.0m of thickness are detected in empty blocks, road sides, park and garden. Since such type of fillings are hard to detect before structuring, with the investigation made in digital environment in the first step, fields with more than 3m of thickness is selected and mapped. In other areas which can create serious problems in terms of thickness distribution, material conent and stability are decided to be studied in detail. The list including the short information of 37 filling areas where detailed studies are performed is given in Chart 11.1, map showing the areas is given in Figure 11.1(Artificial Filling Map).

Filling that are mapped as a result of all of the studies made are classified according to construction management (conrolled – wild), material type, continuity of filling activity, base geometry of filling base, thickness expansion and slope stability and criteria in terms of structuring is specified. According to this: domestic waste-garbage storage areas, chemical waste storage areas, freezed old stone/sand quarry areas and filling field more than 40m thickness are designed as unappropriate in terms of structuring.

## Chart 11.1 List of Filling Areas Studied in Detail

| Province | Threader NO | Filling NO | Filling Material | Filling Type | MAX. Thickness | Base Unit |
|---|---|---|---|---|---|---|
| SANCAKTEPE / YENİDOĞAN | F22C21D | 1 | Earthwork (soil) | Valley filling / Slope filling | 21 | Sultanbeyli Formasyonu |
| BEYKOZ / KAVACIK | F22D17B | 2 | Earthwork Rock | Graben filling / Slope filling | 60 | Pendik Formasyonu (Kartal member-Kozyatağ member) / Sultanbeyli Formasyonu (Tuğlacıbaşı member) |
| USKUDAR / HEKİMBAŞI | F22D18D | 3 | Waste earthwork (Soil) | Valley Filling | 53 | Pendik Formasyonu / Kartal Member |
| ATAŞEHİR / MUSTAFA KEMAL | F22D22C | 4 | Earthwork Soil | Graben Filling | 45 | Pelitli Formasyonu |
| ÜMRANİYE / ÇAKMAK | F22D23D | 5 | Earthwork Soil | Slope Filling | 12 | Kurtköy Formasyonu / Bakacak Member |
| ÜMRANİYE / ÇAKMAK | F22D23D | 6 | Earthwork Rock | Slope Filling | 27 | Kurtköy Formasyonu / Bakacak Member |
| ATAŞEHİR / BARBAROS | G22A03A | 7 | Waste + earthwork(rock) | Graben filling / Flat base filling | 40 | Kocatöngel Formasyonu / Pelitli Formasyonu (Sedefadası member) |
| MALTEPE / BAŞIBÜYÜK | G22A03C | 8 | Waste + Earthwork Soil | Valley filling | 30,5 | Kurtköy Formation / Süreyyapaşa Member |
| KADIKÖY / BOSTANCI(E-5) | G22A03D | 9 | Earthwork(soil) | Slope filling / Valley filling | 25 | Kartal Formation (Kozyatağ member) / Alluvium |
| MALTEPE / BÜYÜK BAKKALKÖY | G22A04C | 10 | Earthwork (rock) | Graben filling / Slope filling | 37 | Talus |
| MALTEPE / BAŞIBÜYÜK | G22A04D | 11 | Earthwork (rock) | Graben filling / Slope filling | 39 | Aydos Formation / Başıbüyük Member |
| KARTAL / OTO SANAYİ | G22A09C | 12 | Earthwork (soil) | Graben filling | 12 | Pelitli Formation / Sedefadası Member |
| MALTEPE / BÜYÜK BAKKALKÖY( ASKERİ ALAN) | G22A10A | 13 | Earthwork (rock) | Slope filling | 23,5 | Yayalar Formation / Gözdağ Member |
| KARTAL / UĞUR MUMCU | G22A10A | 14 | Waste + Earthwork (soil) | Valley filling | 25 | Sultanbeyli Formation (Tuğlacıbaşı member) Yayalar Formation (Gözdağ member) |
| KARTAL / YAKACIK | G22A10A | 15 | Earthwork (soil) | Valley filling / Slope filling | 26 | Yakacık Magmatite Complex |
| KARTAL / UĞUR MUMCU | G22A10A | 16 | Earthwork (soil) | Valley filling | 12 | Sultanbeyli Formation / Tuğlacıbaşı Member |
| PENDİK / GÜLLÜ BAĞLAR | G22B06C | 17 | Earthwork (rock) | Graben filling / Slope filling | 56 | Pelitli Formation (Dolayoba-Sedefadası member) Yayalar Formation (Şeyhli member) |
| TUZLA / KURTKÖY | G22B07C | 18 | Earthwork (rock) | Graben filling | 38 | Sultanbeyli Formation (Orhanlı member) / Aydos Formation |
| TUZLA / TEPEÖREN | G22B09D | 19 | Earthwork (rock) | Graben filling / Slope filling | 17 | Sancaktepe Granite |
| PENDİK / FEVZİ ÇAKMAK | G22B11A | 20 | Earthwork (rock) | Graben filling | 50 | Pelitli Formation / Dolayoba Member |
| PENDİK / FEVZİ ÇAKMAK | G22B11A | 21 | Earthwork (soil) | Graben filling / Valley filling | 36,5 | Pelitli Formation / Dolayoba Member |
| PENDİK / FEVZİ ÇAKMAK | G22B11A | 22 | Earthwork (soil) | Graben filling | 13,5 | Pelitli Formation / Sedefadası Member |
| PENDİK / FEVZİ ÇAKMAK | G22B11A | 23 | Earthwork (soil) | Graben filling | 29 | Yayalar Formation / Şeyhli Member |
| PENDİK / FEVZİ ÇAKMAK | G22B11A | 24 | Earthwork (rock) | Graben filling | 15 | Yayalar Formation / Şeyhli Member |
| PENDİK / SABİHA GÖKÇEN HAVAALANI SAHASI | G22B12A | 25 | Earthwork (soil) | Graben filling / Slope filling | 15 | Sultanbeyli Formation / Orhanlı Member |
| PENDİK / AYDINLI | G22B12A | 26 | Earthwork (soil) | Slope filling / Flat base filling | 15 | Sultanbeyli Formation / Orhanlı Member |
| PENDİK / AYDINLI | G22B12C | 27 | Waste + Earthwork (soil) | Slope filling / Flat base filling | 24 | Yayalar Formation / Şeyhli Member |
| PENDİK / AYDINLI | G22B12D | 28 | Earthwork (rock) | Valley filling / Slope filling | 17 | Yayalar Formation / Şeyhli Member |
| TUZLA / ORHANLI DERİ SANAYİİ | G22B13D | 29 | Waste + Earthwork (soil) | Valley filling / Flat base filling | 21 | Sultanbeyli Formation / Orhanlı Member |
| TUZLA / ORHANLI DERİ SANAYİİ | G22B13D | 30 | Earthwork (rock) | Valley filling / Slope filling | 33 | Sultanbeyli Formation (Orhanlı Member) / Sancaktepe Granite |
| PENDİK / KURTKÖY | G22B07B | 31 | Earthwork (soil) | Graben filling | 28 | Aydos Formation / Kurtköy Formation |
| TUZLA | G22B13B | 32 | Earthwork (soil) | Valley filling/Slope filling | 12 | Sancaktepe Granite |
| ÜMRANİYE | F22D17C | 33 | Earthwork (Rock) | Valley filling/Slope filling | 28 | Pendik Formation (Kartal Member) |
| ÜMRANİYE | F22D18D | 34 | Earthwork (Rock) | Valley filling/Slope filling | 29 | Pendik Formation (Kartal Member)/ Kurtköy Formation (Bakacak Member) |
| ÜMRANİYE | G22A03B | 35 | Earthwork (Rock) | Slope filling / Flat base filling | 23 | Kurtköy Formation (Bakacak-Süreyyapaşa Member) / Alüvyon |
| MALTEPE | G22A05D | 36 | Earthwork (Rock) | Slope filling | 22,5 | Yamaç Molozu/Pendik Formation (Kartal Member)/ Alüvyon |
| PENDİK | G22B07D | 37 | Earthwork (Rock) | Valley filling/Slope filling | 22 | Sultanbeyli Formation (Orhanlı Member) |

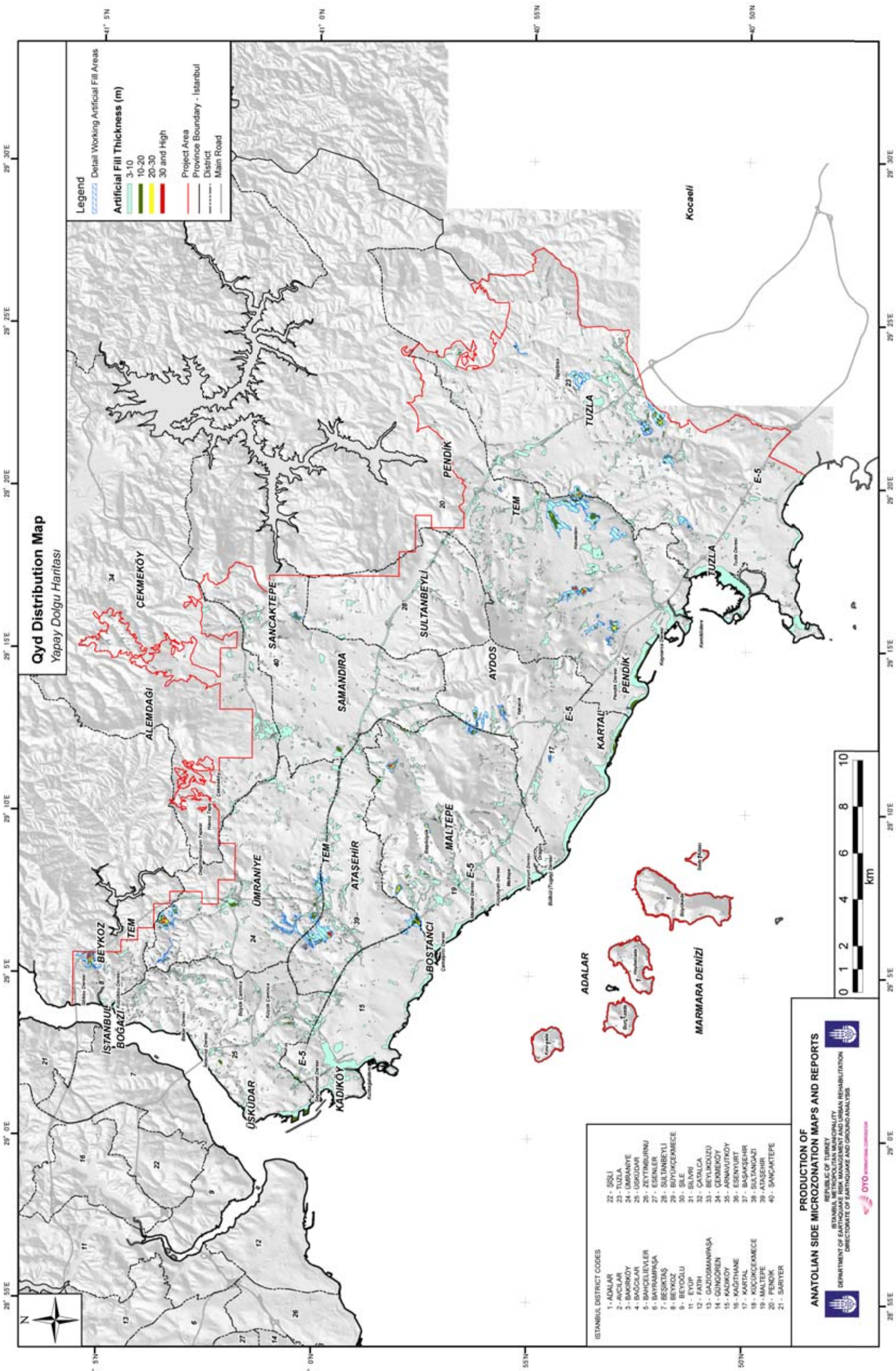



Figure 11.1 Artificial Filling Map

## 12. EVALUATİONS OF SETTLEMENT CONVENIENCE

Main reason of Microzonation, Geologic-Geotechnics etc geological studies which are in different scope, content and format is to make settlement convenience evaluations to identify catasthrope dangers and risks in the areas where structuring is made, preventing catastrophes and limiting their harm.

The settlement convenience evaluation of microzonation reports that generally have multi-purpose (reducing the catasthrope damage, forming a base for conservation planning, urban recycle studies, forming a base for big projects(tunnel, dam, underground depots et), directing feasibility studies) and that are prepared in any type of scale (1/5000, 1/2000, 1/1000) should be reflected to field usage decisions, densities and structuring decisions considering analytical etudes and planning brinks.

In order to evaluate study field in terms of settlement convenience: risk maps that are prepared in the light of field, laboratory and office studies, analyses and foldered all of the former information with newly obtained ones are benefited from. In this context, elements that can affect the settlement convenience are specified and these elements are enhanced with maps to form settlement availability groups.

Settlement convenience evaluation made is prepared from 18 type of maps which concords with the technical matters mentioned in work agreement and these bas maps include any kind of catasthrope risk evaluation. Technical Specifications which is the rider of work agreement and various standards, regulations, notices etc. referring to this agreement are the technical alibi of this evaluation.

While preparing settlement convenience maps and reports of these maps, regulations and notices published by Ministry of Public Works and related units are taken as general criteria. Topics and criteria designated in Format 4 belonging to microzonation studies in accordance with 19.08.2008 date and notice appendix no. 10337 are carefully pursued in the evaluation within the scope and property of the work, and the content of the handbook 'Geological Datas Integration to Planning'' is utilized.

Following risks whose base maps are prepared are paid attention for the evaluation of settlement convenience;

- Liquidization risk
- Mass Movements ( Soil Movements, Rock Slide, Slope Stability, Rock Fall and Toppling)
- Flooding (Rain Water Effect, Tsunami)
- Engineering Problems (Artificial Filling, Alluvium and Kuşdili)
- Other Engineering Problems ( Karsting, Extremely Weathered Rock, Stone and Sand Quarry, Soft Soils)
- Multi-problematic areas where above issues take part together.

After the evaluation of these risks, base maps for each risk is prepared and by Engineering Geology Map that is prepared in direction of these maps Settlement Convenience Maps are produced.

Consequently Project site is divided into 3 main groups in terms of settlement convenience.

(a) Appropriate Areas (AA)

(b) Prudent Areas (PA)

(c) Unappropriate Areas (UA)

### 12.1 Appropriate Areas (AA)

These areas cover 39.14% of the project site. Generally in study field:

They are represented geologically by hard mesozoic or paleozoic layers such as Yakacık Magmatic Complex, Denizliköy, Pendik, Yaylar, Aydos, Kurtköy and Kocatöngel formations' not extremely weathered sections.

### 12.2 Prudent Areas (PA)

These areas cover 60.30% of project site. They have properties that can affect settlement convenience within project site because of their natural catasthrope risks and geologic-geotechnics features, so specific precautions before and during the structiring process is needed.

Furthermore prudent areas are divided into 2 sub areas in terms of problems and density and variousity of precutions to be taken. These are;

PA-a: 1th degree significant areas (Highly Prudent) and PA-b: 2nd degree prudent (Low Prudent) areas.

### 12.3 Unappropriate areas (UA)

Unappropriate areas are areas which are detected to have inconvenient technic and economic precautions because of various natural catasthrope risk and/or geologic and geotechnics problems. These areas cover 0.56% of the project site.

Unappropriate areas area divided into 5 groups as follows:

- UA-1 : Liquidization
- UA-2 : Mass Movements
- UA-3 : Tsunami Flooding and Tsunami
- UA-4 : Engineering Problems (Filling etc.)
- UA-5 : Other Engineering Problems (Quarries etc.)
- UA-6 : Multi Risk Regions

UA-1 area is only partakes in Göksu brook's bosphorus onlooking section in two small area in Beykoz district

UA-2 area partakes in Kınalıada's west and south sea section and south section of Burgazada.

UA-3 area only partakes in small part of sea shore in Kartal Region (Tsunami oriented)

UA-4 Partake in several region inside the working site.

UA-5. area especially observed much inside sections of project site.

UA-6 area is only one in project site and partakes in Kınalıada's south.

As a result of all the analyses made Settlement Convenience Map seen in Figure 12.1 is prepared.

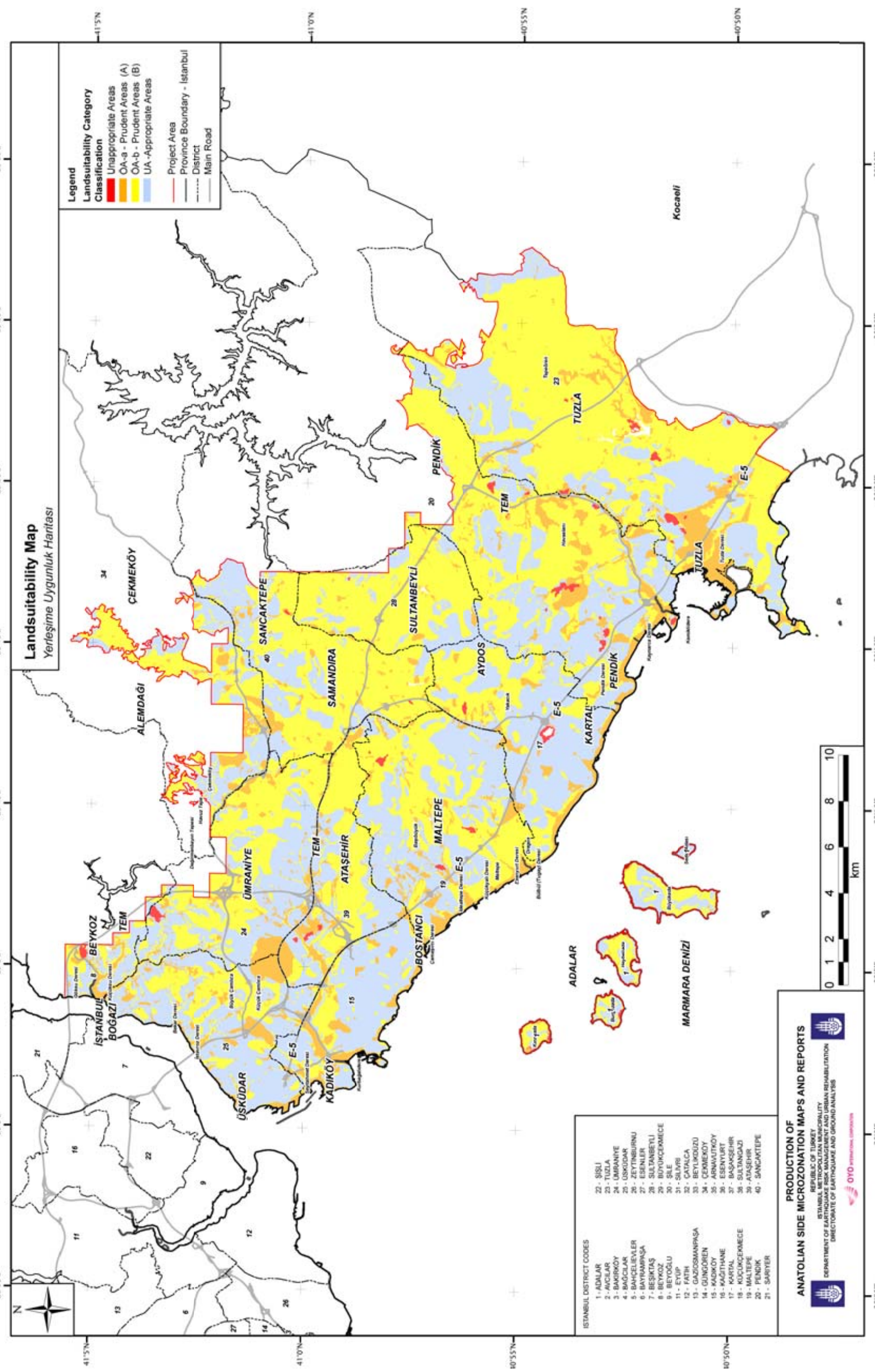



**Figure 12.1 Settlement Convenience Map**

## 13. RESULTS

1. Within the scope of İstanbul Metropolitan Municipality Directorate of Earthquake and Ground Analysis; “PRODUCTION OF MICROZONATION REPORT AND MAPS FOR ASIAN SIDE” work which is the second stage of Microzonation Studies that are conducted within the borders of İstanbul Provincial area, was started on the date of 20.07.2007 by the contract signed between Istanbul Metropolitan Municipality and OYO International Corporation (Head office is in Japan) Turkey Branch, and after a period of 27 months, on the date of 10.11.2009, all site and office studies were finished.
2. Aim of the study is the determination of geological, geotechnical, geophysical features of Anatolian Side, Istanbul Provincial and the areas of Anatolian Side with different hazard potentials in terms of earthquake effect and local ground conditions, creation of the solution suggestions by analysing the detected problems, then preparing the required map productions in the light of the obtained datas and finally by these products preparation of 1/2000 printout scaled ”Land Suitability Maps” which will constitute the basis for the Construction Plans and also for the large scaled studies such as Urban Transformation Projects, Damage Reduction Plans, Planning of Engineering Constructions (tunnel, subway, underground storages, viaduct etc.)
3. The Study Area contains all parts of Üsküdar, Kadıköy, Ataşehir, Ümraniye, Adalar, Sancaktepe, Sultanbeyli, Maltepe, Kartal, Pendik, Tuzla and Çekmeköy counties except water basin and forest lands, south parts of Beykoz County and its total area is 509,60 km$^2$. Whole area consists of 1/2.000 scaled 452 sheets, 1/5.000 scaled 134 sheets.
4. During the entire study totally 378 epmloyees participated in the project including 98 engineers and technical staff, 280 technicians, borers, deputy borers and employees. Also each stage of the studies were inspected on site by the control organization which consists of 13 people commissioned in İMM Directorate of Earthquake and Ground Analysis.
5. The microzonation studies are conducted with the logic of dividing the study area into equal areas by determined cell sizes and collecting enough ground data which will represent the area, in each cell area. In this scope, the study area was analysed by being divided into 250x250 m grids and there is a total of 8788 grids in the study area (16 grids per 1 km$^2$).
6. In the field studies conducted in grids, a total of 5.029 boreholes which have a total depth of 118.047 meters and 377 CPT holes which have a total depth of 4076,22m. were opened and in a total of 4807 locations, geophysical studies were conducted. By the samples taken from soil environment during the borings, a total of 90.088 laboratory tests were conducted and by the samples taken from rock environment 622 laboratory tests were conducted. Also on the suitable samples too that were obtained from these samples, a total of 183 tests and experiments that are aimed at age determination, were conducted.
7. As a result of the analysis conducted according to the field and laboratory study results, 13 main product maps were prepared. Also in order to use during the analysis and production of these main product maps, different scaled (1/150.000 and 1/40.000) 85 midproduct maps (Artifical Fill, Karsting, Rock Class, Mainrock Depth, etc.) were produced too in the scope of project field. Moreover in order to use during the analysis and production of these main

product maps, indepently of the project field, 1m. and 5m. resolution topographical data sets containing whole İstanbul provincial border, were prepared too and by using these data sets it is possible to product topography, slope, aspect and three dimensional stereo image maps. All prepared reports belonging to the studies consist of 2247 pages.

8. Distinctive geomorphologic feature attracting attention in Anatolian Side of Istanbul is the presence of relatively high plains that consist of the hard rocks resisted to weathering and remained from the peneplain which had formed towards actual Black Sea and hills rising from among. In Pre-Middle Miocene, by the collapse of the high altitude area in Marmara Sea region, leaving its place to a shallow inland sea, the drainage network started directing to South, to Marmara and out of Marmara depressions, closed depressions which are controlled by the weakness zones formed by previously existing NE-SW and NW-SE shear faults and where Sultanbeyli Formation is located at present, developed. Also, lowering of Marmara around 100 m in accordance with today and the base levels of marinal terraces belonging to Quaternary which deposited in the valleys drown by the rised sea at interglacial periods, shows that as a whole Marmara region is probably rising although it has slowed down partially at present.

9. 1/2.000 scaled geology map of the study area was prepared, in geological map production studies the method of mapping rock-stratigraphy units in formation and member stages, was followed. The soil and rock units located in the area were mapped by 17 formation, 36 member names. Among these, 3 formations and 12 members represent soil environments, 14 formations and 24 members represent rock environmnets. Kocatöngel, Kurtköy, Aydos, Yayalar, Pelitli, Pendik, Denizliköy, Trakya formations and volcanics represent rock environments, Sultanbeyli formation and Quaternary aged actual deposits represent soil environments. Also there are found Mesozoic aged volcanics too. During the Geological studies, Structural Geology Map showing the discontinuities such as fault, joint and folding, was produced and in this map 8 major regional fault systems that attract attention with their continuities, were mapped. In these studies, there couldn’t be found any site data about the existence of a conspicuous active fault in İstanbul provincial area. By the age determination studies conducted in the project scope, for the first time it was found that Sultanbeyli Formation is Upper Miocene-Pliocene aged and Kuşdili Formation is Holocene aged. Also by this study, again for the first time, it was proved that Sultanbeyli Formation had deposited in the hollows on a high relief base. By using all obtained datas, three dimensional model diagram of the area was prepared.

10. By making geohydrolic environment characterization of lithological units, the hydrogeology map based on geohydrolic environment types, was prepared. By preparing hydrogeological sections which were formed by benefiting from geological sections, hydrogeological environment (underground water storage areas) types, locations and their general features were defined, underground water basin featured regions were determined, it was provided meaning to the borehole water level existence and depth in the ground borings, underground depth contour and underground water altitude (underground water level) contours were drawn, underground water flow directions and underground water catchment/dreinage areas were marked, the construction foundations with one or two basements and underground water areas that concern to deep excavations, were detected. According to this, in the %28,27 part of the project area Underground water level was determined and in %71,80 of these areas, water

level was measured as shallower than 6m. Also in the scope of the study, in the region there was observed and predicted a zone (Tuzla-Aydos line) which has a high potential of forming underground water basin and will be able to be benefited in the scope of the strategies that will be developed about drinking and utility water supply needed after propable earthquake, and the zone was evaluated as it needs advanced research.

11. Engineering geophysics researches which are applied in the microzonation studies consist of the methods aimed at obtaining geophysical sections and physical features of underground. In this scope; in order to reach to the aim seismic refraction and seismic reflection, refraction-microtremor (ReMi), array microtremor measurements, SPAC, MASW (multichannel spectral analysis of the surface waves), SASW, borehole geophysics researches, electrical resistivity methods, ground penetrating radar (GPR) researches etc. were conducted. By considering the lithology, topography, construction frequency and industrial noise of the project area and similar effects; among these, needed methods and approaches were chosen. It was determined that geophysical researches must serve eight purposes mentioned below;

a) Defining geophysical features of 250 m x 250 m grids,

b) Determination of bedrock depths in terms of engineering,

c) Determining borders and depths of fill areas,

d) Examination of slope stability,

e) Determination of dominant ground period,

f) Obtaining AVs30 map for İstanbul damage distribution analysis,

g) Determination of discontinuities,

h) Obtaining earthquake and ground shake parameters such as frequency and amplification.

One of the most important aims of geophysical researches is the determination of bedrock depth distribution. In the determination of geophysical bedrock (the layers whose S wave velocity is higher than 760 m/s) distribution, all of ReMi, MASW, seismic reflection, borehole seismic (PS logging), 2B electric and 2B seismic studies were used. It was observed that produced Geophysical bedrock distribution map corresponds to the geology bedrock distribution map which was produced by evaluating the borings, at a high rate (% 75 – 90).

12. The outcrop distributions of Paleozoic and Mesozoic aged units that form rock environments of the study area, is %61, the outcrop distributions of Neogene and Quaternary aged lithologies which form soil environments was determined as %39. According to the measurement results obtained by the outcrops which are sufficient for the measurement, in whole area, dominant discontinuity directions were determined as NW-SE and NE-SW and also this result corresponds to the tectonic development of the region. According to the rock

quality classification that was made on the rock units located in the project area, it was determined that %51,5 part of outcropping rocks consists of C class rocks and the deepest location of the bedrock is determined as 162nd m. where the bedrock is buried by the ground lithologies. According to the test results conducted in the soil environments, it was detected very soft-soft soils whose thicknesses are more than 10 m., generally in the shore parts, stream mouths and at the inner parts of the valleys, in the plain areas where Kuşdili Formation and Alluvium show distribution and at some inner parts where Sultanbeyli formation distributed.

13. In most of the borings conducted in the distribution areas of Denizli Köyü, Pendik and Pelitli Formations which consist of limestone lithologies, karstic cavities were detected and almost all of the cavities were filled with clay, silt, sand type materials which are named as karstic cavity fill. Therefore subsidence hazard is expected.
14. In the project area, all stream beds connecting to İstanbul Bosphorus and Marmara Sea, beach fills, centre parts of Sancaktepe and Sultanbeyli counties, north part of Tuzla county (east side of Sabiha Gökçen Airport) and north parts of Pendik county (north part of Sabiha Gökçen Airport) were determined as the areas which have liquefaction hazard. These areas have a total of 36.02 km$^2$ distribution, this area correspond to %7,07 of the whole study area.
15. In the project area, as a result of the studies conducted in order to determine active or potential each type of mass movements in earthquake situation and non-earthquake situations, Landslide hazard was detected in 26 sites as a total of 16 are in $A_{SL}$, a total of 7 are in $B_{SL}$ and a total of 3 sites are in $C_{SL}$ hazard group, Rock Slide in 59 slopes, Rock Toppling in 13 slopes and Rock Fall risk in 5 slopes were determined. All of the slopes that have stability problem, form a 17,15 km$^2$ surface as areal, this area corresponds to %3,36 of whole study area. In the most of the areas with stability problem, by the analysis it was proved that this problem developes on the slope debris which is formed on Aydos Formation with higher slope inclination compared to the other formations. Therefore, most of the landslide areas are located on the slopes in Aydos forest where there isn't found settlement.
16. Generally in the middle part of the study area, around Tem and E5 highway route, in total 10 basin area there is seen flood potential depending on heavy rain falls. The highest water level in the floods, was calculated as 2.6 m. and the lowest water level was calculated as is 2.1m. Along whole Marmara Sea and İstanbul Bosphorus shore side, there exists flood hazard because of Tsunami, Tsunami wave height rises over 3 m. at a point in Kartal shore. Except this, in all Asian side shore part the wave height varies between 0- 3m. Although flood hazard depending on earthquake sourced Dam damage, is a quite low probability, in the downstream area of Elmalı Dam, along the stream which is located between Gürani viaduct and Göksu brook bosphorus connection, risk was calculated.
17. The artificial fills thicker than 3 m that show distribution in the project area were mapped. In this scope, a total number of 122 fill areas were analysed insitu, in a total 38 of among these detailed (instrumental) field studies were conducted. In the fields where detailed studies were conducted, the shallowest fill thickness was detected as 12 m. and the highest one was detected as 60 m.

18. Conducted settlement suitability evaluation was produced by 18 kind of maps which were prepared in a way to comply with the technical criterias indicated in the contract of the work, the base maps contain each kind of hazard risk evaluations. In terms of settlement suitability the project area was divided into three (3) major groups as mentioned below.

    a) Suitable Areas (SA) contain % 39,14 of the project area.

    b) Precaution Areas (PA) contain % 60,30 of the project area.

    c) Unsuitable Areas contain (US) % 0,56 of the project area.