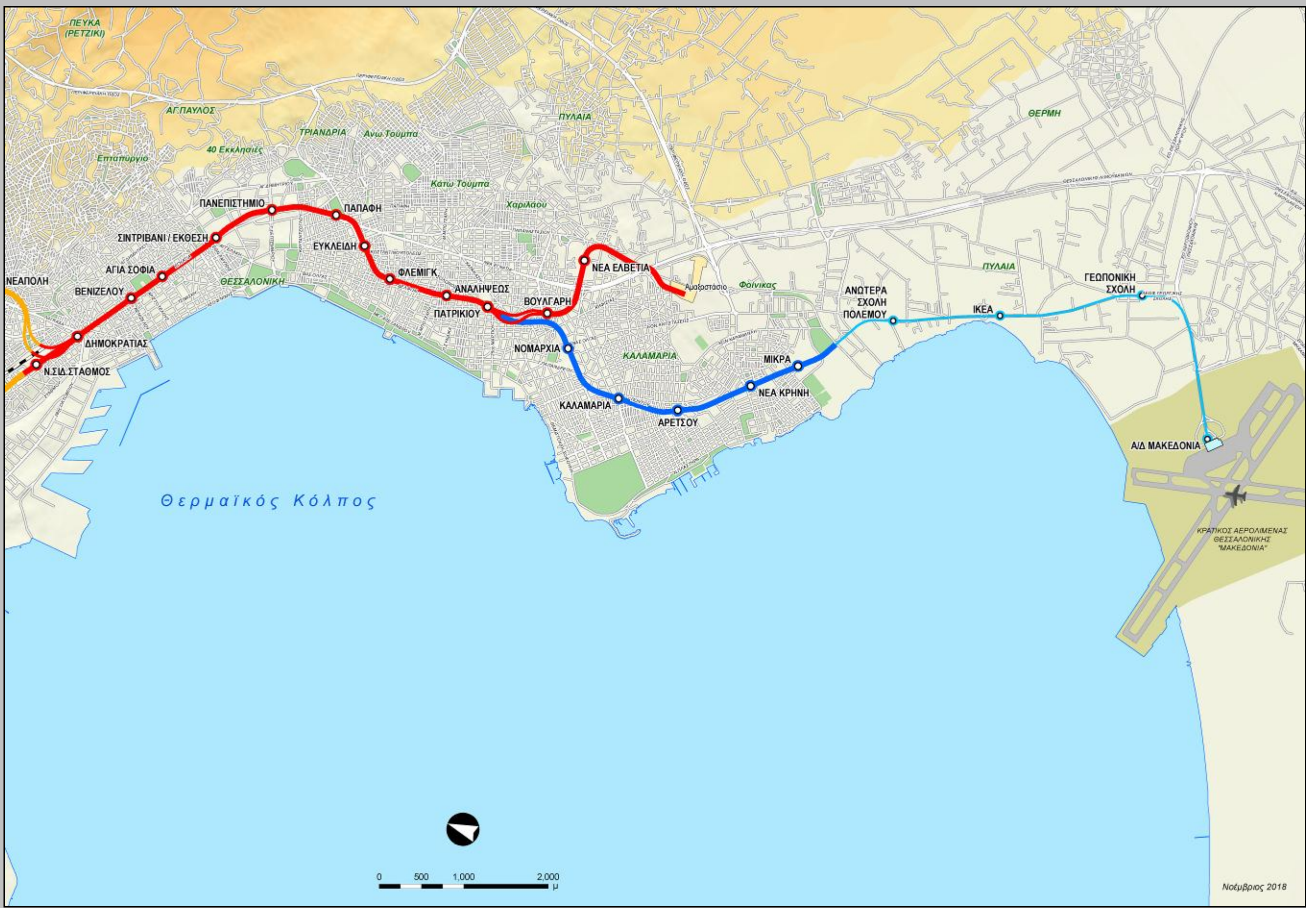
TECHNICAL SPECIFICATIONS



– Page intentionally left blank –

Table of contents

– Page intentionally left blank –

1 Scope

The geological and geotechnical investigations to be executed by the Contractor and all the relevant reports and designs he shall submit shall comply with the content of this document.

The scope of the contract – Framework Agreement – is described in paragraph A.2 of the document entitled *Technical Data*. The works to be executed by the Contractor shall be specified in each Individual Contract of the Framework Agreement.

Data from previous soil investigations executed in areas in proximity to the locations where works will be executed as foreseen in this Framework Agreement shall be made available to the Contractor by AM.

2 Normative references – Terminology

2.1 Normative references

This specification has been compiled on the basis of Eurocode 7 and fulfils the latter's requirements. Approval to the application of the Eurocode was granted via Ministerial Decision ΔΙΠΑΔ/οικ 372 dated 05.06.2014 (Official Government Gazette OGG B 1457/05.06.2014). Eurocode 7 is composed of the following documents:

ELOT EN 1997-1, *Eurocode 7, Geotechnical Design – Part 1: General rules*

ELOT EN 1997-2, *Eurocode 7, Geotechnical Design – Part 2: Ground investigation and testing*

NOTE The two parts of Eurocode 7 are accompanied by the respective National Standards (ELOT EN 1997-1:2005/NA and ELOT EN 1997-2:2007/NA), as their integral parts.

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ELOT EN 1998-1, *Eurocode 8: Design of structures for earthquake resistance – Part 1: General rules, seismic actions and rules for buildings*

NOTE Part 1 of Eurocode 7 is accompanied by the respective National Standard (ELOT EN 1998-1:2005/NA), as an integral part.

ELOT EN ISO 14688-1, *Geotechnical investigation and testing – Identification and classification of soil – Part 1: Identification and description*

ELOT EN ISO 14688-2, *Geotechnical investigation and testing – Identification and classification of soil – Part 2: Principles for a classification*

ELOT EN ISO 14689, *Geotechnical investigation and testing – Identification, description and classification of rock*

ELOT EN ISO 17892-1, *Geotechnical investigation and testing – Laboratory testing of soil – Part 1: Determination of water content*

ELOT EN ISO 17892-2, *Geotechnical investigation and testing – Laboratory testing of soil – Part 2: Determination of bulk density*

ELOT EN ISO 17892-3, *Geotechnical investigation and testing – Laboratory testing of soil – Part 3: Determination of particle density*

ELOT EN ISO 17892-4, *Geotechnical investigation and testing – Laboratory testing of soil – Part 4: Determination of particle size distribution*

ELOT EN ISO 17892-5, *Geotechnical investigation and testing – Laboratory testing of* *soil – Part 5: Incremental loading oedometer test*

ELOT CEN ISO/TS 17892-7, *Geotechnical investigation and testing – Laboratory testing of soil – Part 7: Unconfined compression test*

ELOT EN ISO 17892-8, *Geotechnical investigation and testing – Laboratory testing of soil – Part 8: Unconsolidated undrained triaxial test*

ELOT EN ISO 17892-9, *Geotechnical investigation and testing – Laboratory testing of soil – Part 9: Consolidated triaxial compression tests on water-saturated soils*

ELOT CEN ISO/TS 17892-10, *Geotechnical investigation and testing – Laboratory testing of soil – Part 10: Direct shear tests*

ELOT EN ISO 17892-11, *Geotechnical investigation and testing – Laboratory testing of soil – Part 11: Determination of permeability by constant and falling head*

ELOT EN ISO 17892-12, *Geotechnical investigation and testing – Laboratory testing of soil – Part 12: Determination of liquid limit and plastic limit*

ELOT EN ISO 22282-1, *Geotechnical investigation and testing – Geohydraulic testing – Part 1: General rules*

ELOT EN ISO 22282-2, *Geotechnical investigation and testing – Geohydraulic testing – Part 2: Water permeability tests in a borehole using open systems*

ELOT EN ISO 22282-3, *Geotechnical investigation and testing – Geohydraulic testing – Part 3: Water pressure tests in rock*

ELOT EN ISO 22282-4, *Geotechnical investigation and testing – Geohydraulic testing – Part 4: Pumping tests*

ELOT EN ISO 22475-1, *Geotechnical investigation and testing – Sampling methods and groundwater measurements – Part 1: Technical principles for execution*

ELOT EN ISO 22476-1, *Geotechnical investigation and testing – Field testing – Part 1: Electrical cone and piezocone penetration test*

ELOT EN ISO 22476-2, *Geotechnical investigation and testing – Field testing – Part 2: Dynamic probing test*

ELOT EN ISO 22476-3, *Geotechnical investigation and testing – Field testing – Part 3: Standard penetration test*

ELOT EN ISO 22476-4, *Geotechnical investigation and testing – Field testing – Part 4: Ménard pressuremeter test*

ELOT EN ISO 22476-5, *Geotechnical investigation and testing – Field testing – Part 5: Flexible dilatometer test*

ELOT EN ISO 22476-, *Geotechnical investigation and testing – Field testing – Part 6: Self-boring pressuremeter test*

ELOT EN ISO 22476-7, *Geotechnical investigation and testing – Field testing – Part 7: Borehole jack test*

ELOT EN ISO 22476-8, *Geotechnical investigation and testing – Field testing – Part 8: Full displacement pressuremeter test*

ELOT EN ISO 22476-10, *Geotechnical investigation and testing – Field testing – Part 10: Weight sounding test*

ELOT EN ISO 22476-11, *Geotechnical investigation and testing – Field testing – Part 11: Flat dilatometer test*

ELOT EN ISO 22476-12, *Geotechnical investigation and testing – Field testing – Part*

12: Mechanical cone penetration test (CPTM)

ELOT EN 196-2, *Method of testing cement – Part 2: Chemical analysis of cement*

ELOT EN 1329-1, *Plastic piping systems for soil and waste discharge (low and high temperature) within buildings – Unplasticized polyvinyl chloride (PVC-U) – Part 1: Specifications for pipes, fittings and the system*

ELOT EN 13286-2*: Unbound and hydraulically bound mixtures – Part 2: Test methods for laboratory reference density and water content. Proctor compaction*

ELOT EN 13286-47*: Unbound and hydraulically bound mixtures – Part 47: Test method for the determination of California bearing ratio, immediate bearing index and linear swelling*

ELOT EN 13577, *Chemical attack on concrete – Determination of aggressive carbon dioxide content in water*

ELOT EN 16228-1, *Drilling and foundation equipment – Part 1: Common requirements*

ELOT EN 16228-2, *Drilling and foundation equipment – Part 2: Mobile drill rigs for civil and geotechnical engineering, quarrying and mining*

ELOT EN 16502, *Test method for the determination of the degree of soil acidity according to Baumann-Gully*

ISO 710-1, *Graphical symbols for use on detailed maps, plans and geological cross-sections – Part 1: General rules of representation*

ISO 710-2, *Graphical symbols for use on detailed maps, plans and geological cross-sections – Part 2: Representation of sedimentary rocks*

ISO 710-3, *Graphical symbols for use on detailed maps, plans and geological cross-sections – Part 3: Representation of magmatic rocks*

ISO 710-4, *Graphical symbols for use on detailed maps, plans and geological cross-sections – Part 4: Representation of metamorphic rocks*

ISO 710-5, *Graphical symbols for use on detailed maps, plans and geological cross-sections – Part 5: Representation of minerals*

ISO 710-6, *Graphical symbols for use on detailed maps, plans and geological cross-sections – Part 6: Representation of contact rocks and rocks which have undergone metasomatic, pneumatolytic or hydrothermal transformation or transformation by weathering*

ISO 710-7, *Graphical symbols for use on detailed maps, plans and geological cross-sections – Part 7: Tectonic symbols*

ISO 3310-1, *Test sieves – Technical requirements and testing – Part 1: Test sieves of metal wire cloth*

ISO 3310-2, *Test sieves – Technical requirements and testing – Part 2: Test sieves of perforated metal plate*

ISO 4316, *Surface active agents – Determination of pH of aqueous solutions – Potentiometric method*

ISO 7150-1, *Water quality – Determination of ammonium – Part 1: Manual spectrometric method*

ISO 7393, *Determination of free chlorine and total chlorine*

ISO 7980, *Water quality – Determination of calcium and magnesium – Atomic absorption spectrometric method*

Concrete Technology Regulation (OGG B 1561/02.06.2016)

E 101-83, *Technical specifications for sampling boreholes on land* (OGG B 363/24.06.83, as supplemented by M.D. 6019, para. 2 (OGG B 29/11.02.1986))

E 102-84 and E 103-84, *Specification for In-situ Rock Mechanics Tests and Rock Mechanics Lab Tests* (OGG B 70/08.02.1985)

E 104-85, *Specifications for Geological Works in the framework of Designs for Technical Projects* (OGG B 29/11.02.1986)

E 105-86, *Specifications for Soil Engineering Lab Tests* (OGG B 955/31.12.1986)

ASTM D 854, *Standard Test Methods for Specific Gravity of Soil Solids by Water Pycnometer*

ASTM D 2487, *Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System)*

ASTM D 2850, *Standard Test Method for Unconsolidated-Undrained Triaxial Compression Test on Cohesive Soils*

ASTM D 2974, *Standard Test Methods for Moisture, Ash and Organic Matter of Peat and Other Organic Soils*

ASTM D 3080, *Standard Test Method for Direct Shear Test of Soils Under Consolidated Drained Conditions*

ASTM D 3999, *Standard Test Methods for the Determination of the Modulus and Damping Properties of Soils Using the Cyclic Triaxial Apparatus*

ASTM D 4015, *Standard Test Methods for Modulus and Damping of Soils by Fixed-Base Resonant Column Devices*

ASTM D 4373, *Standard Test Method for Rapid Determination of Carbonate Content of Soils*

ASTM D 4427, *Standard Classification of Peat Samples by Laboratory Testing*

ASTM D 4644, *Standard Test Method for Slake Durability of Shales and Other Similar Weak Rocks*

ASTM D 4767, *Standard Test Method for Consolidated Undrained Triaxial Compression Test for Cohesive Soils*

ASTM D 5311, *Standard Test Method for Load Controlled Cyclic Triaxial Strength of Soil*

ASTM D 5607, *Standard Test Method for Performing Laboratory Direct Shear Strength Tests of Rock Specimens under Constant Normal Force*

ASTM D 6467, *Standard Test Method for Torsional Ring Shear Test to Determine Drained Residual Shear Strength of Cohesive Soils*

ASTM D 7012, *Standard Test Methods for Compressive Strength and Elastic Moduli of Intact Rock Core Specimens under Varying States of Stress and Temperatures*

ASTM D 7625, *Standard Test Method for Laboratory Determination of Abrasiveness of Rock Using the CERCHAR Method*

BS 1377-3, *Methods of test for soil for civil engineering purposes – Part 3: Chemical and electrochemical tests*

BS 1377-4, *Methods of test for soil for civil engineering purposes – Part 4: Determination of maximum and minimum dry densities for granular soils*

BS 5930, *Code of practice for site investigations*

BS 10175, *Investigation of potentially contaminated sites. Code of practice*

ISRM *Suggested Method for Determining Tensile Strength of Rock Materials, Part 2: Suggested Method for Determining Indirect Tensile Strength by the Brazilian Test*

DIN 38414-4, *German standard methods for the examination of water, waste water and sludge – sludge and sediments (group S) – determination of leachability by water*

AASHTO T 194, *Standard Method of Test for Determination of Organic Matter in Soils by Wet Combustion*

Electronic Transfer of Geotechnical and Geoenvironmental Data (Edition 4.0.4), February 2017, Association of Geotechnical & Geoenvironmental Specialists (http://www.ags.org.uk)

Law 2696/1999, *Ratification of the Highway Code* (OGG A 57/23.03.1999)

P.D. 105/1995, *Minimum specifications for health & safety at work signage, in compliance with Directive 92/58/EEC* (OGG A 67/10.04.1995)

P.D. 17/1996, *Measures to improve the health and safety of workers at work, in compliance with Directives 89/391/EEC and 91/383/EEC* (OGG A 11/18.01.1996)

P.D. 305/1996, *Minimum Health & Safety specifications applicable to temporary or movable worksites, in compliance with Directive 92/57/EEC* (OGG A 212/ 29.08.1996)

Decision ΔΕΕΠΠ/οικ/502 dated 13.10.2000, Implementation of Quality Plans in pubic works and designs (OGG B΄ 1265/18.10.2000)

Decision ΔΙΠΑΔ/οικ/369 dated 15.10.2012, Integration in the contract documents of tendered projects of an article related to the "necessary health and safety measures in worksites" (ΑΔΑ: Β4301-8ΞΩ)

Decision ΔΙΠΑΔ/οικ/501 dated 01.07.2003, Approval of directives of compulsory application concerning the content, control and approval of Design Quality Plans (OGG B 928/04.07.2003)

Decision No. ΔΙΠΑΔ/οικ/502 dated 01.07.2003, *Approval of the Technical Specification for Signage on current Road works executed in residential/non-residential areas as a minimum* (OGG B΄ 946/09.07.2003)

Decision ΔΙΠΑΔ/οικ/889 dated 27.11.2002, Preventing and addressing work-related hazards in the construction of Public Works (SHP and HSF) (OGG B 16/14.01.2003)

Decision No. 6952 dated 14.02.2011 issued by the Ministries of Environment and Infrastructures. *Obligations and measures for the safe circulation of pedestrians during the execution of works in public areas designated for pedestrians* (OGG B΄ 420/16.03.2011)

EPA-823-B-01-002, *Methods for Collection, Storage and Manipulation of Sediments for Chemical and Toxicological Analysis: Technical Manual, 2001, U.S. Environmental Protection Agency (U.S.E.P.A.)*

EPA method 8015, *Nonhalogenated organics using GC/FID, U.S. Environmental Protection Agency (U.S.E.P.A.)*

APHA method 5520-C, *Standard methods for the examination of water and wastewater – Oil and grease – Partition-Infrared method, American Public Health Association*

A list with all the standards the Contractor intends to use shall be submitted for approval to AM, as part of the Geotechnical Investigation Programme (§ 11.3.3.1) and of the Geological Investigation Programme (§ 11.3.3.2).

2.2 Terms and definitions

The terminology is based on Eurocode 7 (ELOT EN 1997-1 and ELOT EN 1997-2) and its normative references, with the exception of paragraphs 2.2.2, 2.2.3, 2.2.5, 2.2.8, 2.2.13, 2.2.15, 2.2.16, 2.2.17 and 2.2.19. The following are the key terms, as well as their definitions as used in this specification.

NOTE Terms and definitions related to soil classification are presented in §18.3.

2.2.1 anthropogenic soil

soil placed by human activity which can be divided into those composed of reworked natural soils and those composed of synthetic materials

NOTE Anthropogenic soil that can be further divided into *fill*, when deposit is placed with engineering control, or into *made ground* or *reconstituted ground*, when the deposit is placed without engineering control.

2.2.2 maximum groundwater level

the maximum groundwater level for an extreme hydrological cycle (maximum level for a 100 years return period)

NOTE The maximum groundwater level is used for the design of permanent structures.

2.2.3 Project axis

for the needs of this specification, "Project axis" refers to the line that runs between the two rails, at an equal distance from each other.

2.2.4 rock material, intact rock

intact rock between the discontinuities

NOTE Intact rock generally presents an unconfined compressive strength higher than 600kPa.

NOTE Intact rock may present textural characteristics which affect its isotropy (schistocity, grain and mineral orientation etc.) which should be taken into consideration for the assessment of laboratory data with regard to the final strength parameter selection.

NOTE Strength and deformation parameters of the intact rock are directly determined based on laboratory tests.

2.2.5 AGS Format data file

a data file for the electronic transfer of geotechnical and geological / environmental data which is compiles according to standard "*Electronic Transfer of Geotechnical and Geoenvironmental Data (Edition 4.0.4)* (Association of Geotechnical & Geoenvironmental Specialists, February 2017)

2.2.6 rock mass

rock comprising the intact material together with the discontinuities and weathering zones

NOTE Rock mass generally consists of rock material blocks delimited by geological discontinuities (joints, bedding planes, faults, shear planes etc.), not excluding, however, soil geomaterial participation.

NOTE Since it is not usually possible to obtain representative rock mass samples, strength and deformation parameters of the rock mass are usually indirectly determined by correlating laboratory tests on rock material samples and use of rock mass classification systems. Rock masses with few and infrequent discontinuities are an exception to the above; the influence of the said discontinuities to the behaviour of the rock mass as to its deformation is negligible. In these cases, rock material samples are representative of the rock mass and, therefore the determination of strength and deformation parameters can be directly achieved based on laboratory tests on rock material samples.

2.2.7 rock

naturally occurring assemblage or aggregate of mineral grains, crystals or mineral based particles, compacted, cemented or otherwise bound together and which cannot be disaggregated by hand in water

2.2.8 geological formation

the term 'geological formation' corresponds to the term 'formation' *sensu stricto* [1]

NOTE 1 According to ISSC (1994) (International Subcommission on Stratigraphic Classification of IUGS International Commission on Stratigraphy: International stratigraphic guide (2nd edition, Amos Salvador, ed.)), *"Formation. The primary formal unit of lithostratigraphic classification. Formations are the only formal lithostratigraphic units into which the stratigraphic column everywhere should be divided completely on the basis of lithology. The contrast in lithology between formations required to justify their establishment varies with the complexity of the geology of a region and the detail needed for geologic mapping and to work out its geologic history. No formation is considered justifiable and useful that cannot be delineated at the scale of geologic mapping practiced in the region. The thickness of formations may range from less than a meter to several thousand meters"*.

NOTE The geological formation is made up of engineering geological units of a common origin (e.g. deposition environment) and tectonic history, which have been formed within the same lithostratigraphic age. Usually, the units of a geological formation belong to the same category of rocks (sedimentary, igneous, metamorphic), except for the cases of sequences of formations of different categories (e.g. sedimentary and volcanic) which have been created within the same environment (e.g. typical sequence with sub-volcanic beds that have been deposited to a sea basin). The geological units are described and presented on the geological maps. The project's wider area is a representative scale of the geological formation.

2.2.9 borehole

hole of any predetermined diameter and length formed in any geological formation or man-made material by drilling

NOTE Investigations carried out in such a hole can be to recover rock, soil or water samples from a specified depth or to carry out *in-situ* tests and measurements.

2.2.10 sample

portion of soil or rock recovered from the ground by sampling techniques

2.2.11 specimen

part of soil or rock sample used for a laboratory test

2.2.12 soil

aggregate of minerals and/or organic materials, which can be disaggregated by hand in water

NOTE The term is also applied to anthropogenic soil consisting of materials exhibiting similar behaviour but reworked or artificially made, e.g. embankment fill, crushed rock, mine tailings etc.

NOTE Soil generally has unconfined compressive strength lower than 600kPa. Strength and deformation parameters of soils are directly determined based on laboratory tests, as soil behaviour in project scale and sample scale is generally similar.

2.2.13 trial pit

open excavation constructed to examine the ground conditions in situ, recover samples or carry out field testing

2.2.14 lithological unit

natural aggregation of one or more minerals or rock fragments defined by its petrological composition, predominant grain size, structure, texture and genetic origin

NOTE Lithological unit is a geological unit with uniform geological characteristics at a mesoscopic scale

NOTE Rocky lithological type also called *petrographic type* or simply *rock*

NOTE The representative scale of the lithological unit is the specimen.

2.2.15 pre-excavation pit

any hand excavated pit carried out for the inspection and investigation of surface layers and the existence of PUO networks

2.2.16 engineering geological formation

engineering geological unit with relatively uniform, in project scale, geological and geotechnical characteristics

NOTE An engineering geological formation can be made up by one or more engineering geological units. The engineering geological formations are defined and described during the evaluation of the geological and geotechnical investigations and are presented in the Geological – Hydrogeological –

Geotechnical Longitudinal Section. The project's structures are a representative scale of the engineering geological unit.

2.2.17 engineering geological unit

engineering geological unit with relatively uniform, in a macroscopic scale, geological and geotechnical characteristics

NOTE An engineering geological unit can be made up by one or more petrographic types. The engineering geological formations are separated and described during the description of the borehole cores and are presented in the Borehole Logs. The representative scale of the engineering geological formation is the borehole.

2.2.18 ground

soil, rock and fill in place prior to the execution of the construction works

2.2.19 high groundwater level

the maximum level of a normal hydrological cycle (maximum annual level)

NOTE The high groundwater level is used for the design of temporary structures.

3 Health and Safety

3.1 General – Basic Requirements

The Contractor is exclusively and unreservedly responsible before AM to ensure that workers, work crews, third parties (AM employees, consultants and the Contractor's suppliers, self-employed, visitors, citizens) shall comply in all aspects and throughout the execution of the Project with the applicable legislation, the Provisions and the Regulations related to Health, Safety, Fire-safety and shall comply with the Regulations specified by AM. If a Greek or an EU Legilation is lacking, the current optimum practice shall apply.

The Contractor shall ensure safety of all contract-related works and shall proceed with all necessary actions, in order to ensure the safety of all persons in or in proximity to the worksite, including the workers (if any) of Public Utility Organizations.

The Contractor shall carry out the works of the Framework Agreement in full compliance with the applicable Greek legislation on H&S of Workers and with the standards ELOT EN 16228-1 and ELOT EN 16228-2. The stipulations of the following paragraphs also apply.

AM shall bear no responsibility whatsoever for labor accidents to the Contractor's workers. The Contractor is exclusively responsible for labor accidents or damage to third party property caused by/due to his own activities or omissions.

The Contractor shall report immediately to AM any incident causing injury to his personnel or third parties or any damage to property, irrespective of severity or significance, as well as any hazardous incidents caused by his own activities or omissions.

The Contractor shall immediately comply with all AM instructions and directions concerning the safety of the works.

AM reserves the right to request stoppage of works, removal of the Contractor's Personnel and Equipment and/or expulsion of Work Crews if it is substantiated that the Safety measures provided for by the Framework Agreement and foreseen by the Legislation are not adhered to. This person cannot return to the work area without AM's prior written consent.

Should the Contractor receive a notification for violations ascertained further to the inspection carried out by AM's Department concerned or by any State Authority, he shall immediately notify AM by transmitting copies of the relevant notifications (unless the notification has been issued by AM) and shall proceed with all necessary corrective actions, in line with the relevant requirements of AM's Department concerned or any State Authority.

Should an act or omission of the Contractor results in the imposition of fines to AM by any State Authority or this act or omission burdens AM with expenses related to the implementation of the applicable legislation concerning safety, then the Contractor shall pay and/or compensate AM for all the relevant costs and expenses. Administrative fines imposed by State Authorities due to the failure of the Contractor, his work crews or his Suppliers to comply with the above, shall be exclusively borne by the Contractor.

The Contractor shall appoint the *Safety Technician* to the local Labour Inspection Authority as per Law 3850/2010 and Presidential Decree 17/1996. The announcement to the local Labour Inspection Authority of the assignment of duties to the Safety Technician shall be made prior to the commencement of the works by the Contractor and further to AM's approval.

The Contractor may also appoint a *Safety Officer* per location of drilling machine. The Safety Officer shall assist the Safety Technician on safety related matters. The Safety Officer substitutes for the Safety Technician on safety related matters whenever and wherever he cannot be present. The Safety Officer is entitled and under the obligation to intervene and interrupt all works he/she considers to be hazardous. Other duties may also be assigned to the Safety Officer (person in charge of geotechnical survey field works, drill geologist). The Safety Officer shall be accountable to the Contractor in terms of the implementation of health and safety related issues.

Before commencement of the works, it is strongly advisable that the Safety Technician and the Safety Officer meet with the AM's safety representatives, in order to discuss and agree on the safety measures to be introduced at the worksites.

The Contractor shall provide full access to all relevant files (e.g. accident investigations, omission reports, disciplinary violations etc.) and documentation (training, certificates, maintenance manuals, Safety Technicians contracts, etc.). AM reserves the right to carry out onsite inspections or detailed checks whenever deemed advisable.

3.2 H&S of personnel

The Contractor shall ensure that all worksite personnel has received proper training and is properly supervised so as the safety of the personnel itself as well as of any other persons in the worksite is ensured.

The Contractor shall train its personnel to cope with fire risks and shall supply the appropriate (type and number) of fire extinguishers.

The Contractor shall equip all personnel with high visibility vests.

It is mandatory for all personnel engaged in drilling works to utilize all Personal Protection Equipment (PPE) deriving from the risk analysis (for example: safety helmet, safety boots, gloves, protective goggles, ear-plugs, etc.).

The Contractor shall supply and maintain throughout the duration of the geotechnical investigations all the aforementioned PPE that is necessary for the protection and safety of all persons (personnel or third parties).

Entrance to a fenced worksite area is permitted only to the Contractor's personnel and AM's supervisors, as long as they are equipped with the appropriate Personal Protection Equipment.

The Contractor shall provide employees with working uniforms. It is advisable that working uniforms should bear the Contractor's name.

The Contractor shall introduce all measures required for the supply and installation of a movable toilet unit and a first-aid kit.

3.3 H&S for drilling worksites

The Contractor shall fence the entire working area using 1.8 m high movable frames with metal mesh, dressed with appropriate netting or other appropriate material. The aforementioned fencing shall bear the appropriate traffic signs and the Project's sign (para. 5.6.3), as well as flashing lights marking hazardous conditions during night hours (based on PD 105/1995). For safety reasons, Contractor's works shall be executed within the fenced worksite area. In case the working area is exposed to traffic related risks (in this case, a permit and/or a traffic study are required, see para. 5.6.2), then fencing shall be supplemented with standardised concrete blocks or other similar items (e.g. standardized plastic blocks of New Jersey type, filled with sand or water), properly placed on the side of the traffic, with no gaps between the blocks. The worksite entrance shall be locked during the hours that works are not being executed.

The Contractor shall be responsible for worksite guarding and all relevant cost shall be borne by the Contractor.

The Contractor shall submit a standard borehole worksite in line with the requirements of para. 5.3.

If sidewalks at borehole worksites have been occupied or if the circulation of pedestrians is obstructed, then the Contractor, prior to the occupation or obstruction, shall submit to AM for approval drawings/sketches recommending alternative safe pedestrian circulation paths. The safe paths shall be configured as follows; they shall have wooden deck and protective handrail; blocks of concrete or other suitable material on the traffic side; fencing on the rig side and all necessary traffic arrangements and signs. In general, with regard to the cases in which occupation of sidewalks and/or other public pedestrian circulation areas is required, then the requirements stipulated in Ministerial Decision 6952 shall apply.

Before commencing any drilling activities, and in order to ensure that there are no underground PUO networks at the drilling location, the Contractor shall excavate the pre-excavation pit as described in para. 6.5.2.

NOTE To this end, the use of Cable Avoidance Tools (CAT) is recommended.

Should any pits remain open after their excavation and the Contractor has not installed the drilling worksite, then the Contractor shall supply the appropriate fencing or covering, signage and/or lighting in order to ensure third parties safety.

In the worksite, the Contractor shall ensure continuous telecommunication in case of emergencies (damage, accident, etc.) and for reasons of communicating with the central premises of the Contractor or AM's supervising personnel. The emergency telephone numbers shall be notified to AM prior to the commencement of works.

The Contractor shall deliver to AM the *Material Safety Data Sheet* for all hazardous material to be (eventually) used in the subject Project. The relevant approvals must be obtained for each material falling under this category, every time such a material is used in the Project.

3.4 H&S regarding mechanical equipment

All equipment of the Contractor shall be as determined by the European Legislation and shall bear the CE marking, as stipulated in the applicable legislation, as well as all relevant documentation (e.g. manuals, maintenance books) proving the capability of the equipment to function safely. The Contractor shall ensure that all safety tests, measurements and inspections foreseen by the law are implemented on the equipment. Copies of the certificates shall be available in the drilling worksite to be reviewed by AM.

The compressed air pipework or the piping system for the pressurize oil drilling rig lubrication system (pressure > 10 atm) shall be equipped with whip checks.

The drilling rig shall be equipped with emergency buttons, as required by the manufacturer.

Rigs shall commence their drilling activities only on condition that all safety related requirements are met (fencing, appropriate signage, personnel protection equipment, pre-excavation pit, returned flushing medium closed circuit, screens for movable part, etc.).

Special attention is required when the drilling rig derrick is raised in the presence of overlaying power supply cables.

3.5 Health and Safety Plan (HSP)

The Health and Safety Plan shall be prepared and submitted in line with the requirements of §11.2.1.

4 Design Quality Plan

The Design Quality Plan shall be prepared and submitted in line with the requirements of §11.2.2.

5 Organization of borehole worksites

5.1 Geotechnical Investigation Organization Chart

For the execution of the works pertaining to the Geotechnical Investigation, the Contractor shall employ – as a minimum – the following personnel (members of the Engineering Group and other personnel):

- *Head of Geotechnical Investigation Field Works* (based on the requirements of article 20.2.2.a of the Invitation): He shall be responsible for the supervision and the proper execution of drillings and on site testing.
- *Head(s) of Laboratory* (based on the requirements of article 20.2.2.a of the Invitation): The Heads of Laboratory shall be responsible to sign the laboratory test reports and shall have overall responsibility for the technical functions of the laboratory. Moreover, he/they shall participate in the selection of samples for the execution of the laboratory tests.
- *Head of Engineering Geological Description* (based on the requirements of article 20.2.2.a of the Invitation). The Head of Engineering Geological Description shall execute the descriptions of borehole cores, in line with the content of this document.
- *Rig Geologists (university graduate)* (based on the requirements of article 20.2.2.a of the Invitation): They will be the persons responsible for the supervision and the proper execution of sampling drillings and on site testing.
- *Foreman of Field Works*: one foreman with an at least eight (8)-year similar professional experience in boreholes. The Foreman of Field Works shall be responsible for the drilling rig crews and shall provide technical assistance to them throughout the execution of the Geotechnical Investigation Field Works.
- *In situ Tests' Personnel*: trained and experienced personnel for all types of in situ tests foreseen to be executed in line with the scope of each Individual Contract.
- *Drilling rig operators*: one (1) drilling rig operator per drilling rig.
- *Assistants*: at least one (1) per drilling rig.

The *Geotechnical Investigation Organization Chart* shall be submitted as part of the Geotechnical Investigation Programme (see §11.3.3.1). The organization chart shall also include a list with the names of all the employees from all disciplines.

More precisely, for the execution of pumping tests the Contractor shall employ as a minimum the following personnel (members of the Engineering Group and other personnel):

- *Head of Pumping Tests*: He shall be a (university graduate) Geologist with proven experience in scheduling, monitoring, processing and assessing of a pumping test executed in a pumping well. The Head of Pumping Tests may be one of the Geologists (University Graduates) covering another position of the specialized personnel described in this paragraph.
- *Personnel for the execution of ground water level measurements*: depending on the planning of the pumping tests, the necessary number of personnel to execute ground water level measurements at the pumping wells and at the observation piezometers shall be employed.

The Organization Chart for the execution of pumping tests –if required– shall be submitted as part of the Geotechnical Investigation Programme (see §11.3.3.2). The organization chart shall also include a list with the names of all the employees from all disciplines

5.2 Supervision of Works – Drilling Works Log

The *Head of Geotechnical Investigation Field Works* of the Contractor shall be responsible for the supervision for field works and for any other activity related with the operation of the worksites.

The *Head of Geotechnical Investigation Field Works* shall also keep the Drilling Works Log, in line with the requirements of §3.6.1 of Specification E101-83.

5.3 Borehole worksites

The Contractor shall submit to AM for approval, as part of the Geotechnical Investigation Programme, drawings or sketches of the standardized borehole worksites, showing all equipment (drilling rig, setting tank para. 5.4.2 etc.), the fencing (type, location), the safety signage, the location and type of fire extinguishers, the first aid kit, the Project sign (para. 5.5.4), the light signage during night hours, etc. Signage shall consist of safety signs as per PD 105/1995 and signs described in L. 2696/1999 (Highway Code Ratifying Law), all according to Decision No ΔΙΠΑΔ/οικ/502.

In addition, the requirements specified in para. 3.3 also apply.

5.4 Mechanical equipment

The Contractor shall provide an adequate number of drilling rigs (at least the drilling rigs included in his Offer, in line with para. 20.1.d of the *Invitation*) in order to carry out all necessary works, specified in the Framework Agreement, in accordance with the present specification and within the approved time schedule. The Contractor shall comply with AM requirements with regard to the provision of additional mechanical equipment, in any phase of the execution of works, as long as the requirements of the approved time schedule are not adhered to.

The Contractor shall adduce to the worksite properly maintained drilling rigs possessing the necessary stability, power, as well as the adequate drilling equipment, such as drilling rods, pipes, drilling bits, core barrels and samplers, in order to ensure the specified sampling category, the in situ tests up to the required drilling depth depending on the geological and hydrogeological conditions, in line with the requirements of this document.

Controls and maintenance procedures of the mechanical equipment will be conducted thoroughly by the Contractor according to the directions issued by each device manufacturer and the *in-situ* needs of the Project and there will always be an appropriate spare parts stock at the site in order to address immediately all problems related to the operation of the mechanical equipment without creating any problem or interruption to the works.

The drilling rigs and the drilling equipment (core barrels, samplers, pipes, drilling rigs etc.) shall be selected in line with provisions of §4 and §5 of ELOT EN ISO 22475-1.

The Contractor shall submit a detailed table describing the mechanical equipment to be used, as a part of the Geotechnical Investigation Programme (see para. 11.3.3.1 herein) which will include, as a minimum, the number and the type of the drill rigs, the pumps and the air compressors of the *in-situ* tests, the pressuremeter test equipment, the air lift devices and the Standard Penetration Test arrangements as well as the number, the type and diameters of core barrels and samplers.

In addition, the requirements specified in para. 3.4 also apply.

5.5 Environmental requirements

5.5.1 Control of noise and vibrations due to the executed works

During the execution of the works, the Contractor shall check the noise and vibration levels and maintain them as low as possible. Moreover, the Contractor is obliged to adhere to the requirements relating to rest hours, especially in residential areas.

5.5.2 Waste handling

During the execution of the drilling works, the returning flushing medium shall be piped through a closed circuit in a 3-compartment settling tank, wherein the particles are set and clean water is used again in the drilling.

NOTE A sketch of the settlement tank shall be included in the Geotechnical Investigation Programme (§11.3.3.1).

The Contractor, on a regular basis and in compliance with the instructions of AM, shall remove from the worksite the muck deposits and shall transport and dispose the liquid waste, which remains in the special bins, to a designated disposal area, located far away from the worksite. <u>The disposal of waste to the storm water or sewerage system is not permitted unless Contractor has obtained the written permission of the responsible Authority for their handling.</u>

5.5.3 Contamination control

A contamination survey shall be carried out with AM's consent where potentially contaminated ground is suspected or has been found as a result of relevant investigation, visual indication or other investigation, as indicated in paragraphs 7.5.5 and 8.4 herein. In case there are contaminated samples, in any stage (during the drilling of the borehole, during the description of the boreholes, during tests), AM is informed immediately.

5.5.4 Water supply

The Contractor is responsible for ensuring the supply and the disposal of the required quantity of water to be used in drilling works.

5.6 Deployment and execution of works – Third party relations

5.6.1 Drawings of borehole positions for execution

Prior to the commencement of the relevant works, the Contractor shall prepare a layout showing the location of the boreholes proposed by this Geotechnical Investigation and the boreholes of previous investigations. This layout is submitted as part of the Geotechnical Investigation Programme.

The Contractor shall use topographical drawings of the area where he shall execute his works which will be made available by AM. The scale of the drawings will be such as to facilitate the procedure for the approval of the works and the issuance of permits by the responsible authorities and also allow the exact representation of the location of the drilling (to be shown by a sketch).

If the position of the borehole must be slightly shifted or if the borehole cannot advance past a certain depth due to the prevailing conditions (e.g. identification of an unknown network or encountering of another obstacle), the Contractor shall agree with AM on the relocation of the position, shall proceed, if necessary, to the issuance of a new permit and shall execute the borehole at a new location. The location of the borehole shall be indicated temporarily on a sketch. In case of borehole relocation, the sketch shall show the abandoned position and shall describe the reasons for which the change has been requested.

The final location of the borehole shall be recorded on a sketch in line with the content of para. 6.15.

5.6.2 Ensuring work permits

The Contractor is responsible for obtaining the required permits in order to perform the drilling in the specific location, as per the Ground Investigation Programme. As soon as the implementation of drilling locations are finalised, the Contractor must contact the responsible agencies (Municipal Authority, Regional Authority, Ministry of Infrastructure, Transportation and Networks, designated Archaeological Department, Traffic Police, private entity, etc.) in order to ensure the required written permit regarding the exact location of the drillings, their depths, areas of occupation and the time period required for the execution of the works.

In case the drilling is performed on a road surface, and especially on highways, avenues or streets, where public means of transportation circulate, the Contractor is obliged to obtain the required permits from the responsible agencies (Ministry of Infrastructure, Transportation and Networks, Traffic Police, OASA, etc.), submit all necessary traffic signs and regulations for approval to the designated authorities and during the execution of the works he is obliged to undertake all required safety measures regarding the passing-by vehicles and pedestrians and strictly adhere to the instructions of the Traffic Police and the traffic arrangements and signs.

If the borehole is situated on a private property, the Contractor shall contact the owners of the property. Upon description of the works that are to be executed, the Contractor shall ensure their written consent for the execution of the drilling works. The communication between the Contractor and the private property owners shall be dully documented (e.g. correspondence, electronic correspondence, etc.) and shall be copied to AM.

As per Decision no. 6952 of the Ministers of the Environment and Energy & the Transport and Networks Ministries, (OGG B 420/16.03.2011) (article 5, para. 3) "*The permit to occupy a sidewalk, etc., in public areas of cities and communities intended for pedestrian circulation is granted only after the configuration and marking of the pedestrian circulation path is indicated on drawing. In case the road pavement is occupied, the permit is granted upon consent of the service responsible for the road maintenance. In case the traffic is diverted, a traffic regulation design must be prepared and approved in advance by the service responsible for the road maintenance*."

The Contractor shall access the area where the works are to be executed, shall install his equipment and shall execute the works, only after having obtained the required permits.

5.6.3 Project signage

Signs shall be installed by the Contractor with AM's consent on top of the fencing of each drilling worksite. The sign shall include the name of the Project, the Project Owner, the name of the Contractor, Project funding data, etc.

5.6.4 Protection against damage

The Contractor is obliged to take all required protection measures against damage that may be inflicted both to his equipment and to third parties' material properties.

5.6.5 Interference with land interests

Having obtained the required permit and prior to the commencement of the works, the Contractor is obliged to contact and co-operate with land owners, neighbours, shop owners or any other parties, whose activities may be adversely affected by the execution of the drilling. The Contractor shall inform them on the purpose of the project, the time period required for its execution and shall assure that disturbance due to the works shall be limited to the minimum possible extent. In addition, the Contractor shall fully reinstate the area following completion of the works (see also para. 6.14 herein).

5.6.6 Procedure for complaints and claims on damage

In case complaints are expressed by any adversely affected parties, the Contractor is obliged to respect them and investigate the matter in question. The Contractor shall inform AM Communication Division on the above-mentioned complaints and claims. In case of damage at the Contractor's responsibility, the Contractor is exclusively liable to rectify any damage and/or to compensate the parties that sustained the damage.

6 Specifications for geotechnical investigations – Boreholes and sampling

6.1 Borehole requirements

Boreholes shall be designated by a unique code defined in line with Appendix F.

The total length of the borehole to be measured and compensated shall be equal to the length deriving from the elevation of the bottom of the pre-excavation pit (drilling starting point) minus the elevation of the bottom of the drilling. The final length of the borehole shall be measured along its axis with the drilling rods in the presence of an AM representative who will be given a 1-day notice.

Boreholes shall be drilled outside the Project envelope and at a distance ranging from 2 to 10m from its sides, unless otherwise specified or further to AM's relevant suggestion.

NOTE Piezometers bored at a distance from the Project are exempted from this requirement.

The depths of the boreholes (sampling boreholes, piezometric boreholes, CPT) shall be designed in line with the requirements of Eurocode 7: ELOT EN 1997-2, §2.4.1.3.(6) and Annex B.3 and shall be proposed by the Contractor in the Geotechnical Investigation Programme (see §11.3.3.1).

<u>Sampling in sampling boreholes</u> shall be continuous. Piezometers shall be installed in all sampling boreholes, unless otherwise required by AM. The Contractor shall propose in the Geotechnical Investigation Programme the locations and depths of the sampling boreholes as well as the design of the piezometers to be installed in the boreholes (see §11.3.3.1).

Additional <u>piezometers at a distance from the Project</u> shall be installed in order to draw the piezometric maps described in paras. 9.3.11 and 11.6.1. In general, these boreholes shall be drilled without sampling, unless otherwise required by AM or if sampling is rendered necessary due to the in situ conditions. The above also applies in case of the presence of water at depths which affect the Project.

Pressuremeter boreholes shall be drilled in soils and in weak rocks or rock masses. If pressuremeter boreholes are not sampling ones, these can be drilled adjacent to sampling boreholes.

CPT boreholes shall be drilled for the execution of in situ cone penetration tests at various locations of the Project.

The Contractor shall drill pumping wells and observation piezometers in order to execute pumping tests in areas where the hydrogeological characteristics are deemed of critical importance for the design of the Project. The requirements on the pumping wells and the observation piezometers are provided in §9.3.14.

The number and the locations of all the boreholes of the geotechnical investigation (sampling boreholes, non-sampling boreholes with piezometer, pressuremeter boreholes, CPT, pumping wells) shall be defined by AM or AM shall request the Contractor to define them depending on the scope of each Individual Contract. The number, the locations, the depths and the planning of all boreholes shall be submitted for approval in the framework of the Ground Investigation Programme (see §11.3.3).

6.2 Sampling requirements

The rock, soil and water sampling works in boreholes shall be executed in line with standard ELOT EN ISO 22475-1 and the stipulations of the subsequent paragraphs.

The sampling category of soils and rocks and quality class of soil samples will be the minimum required by case, depending on the laboratory test which is planned for each specimen according to Table 6.1 (for soil specimens) and paragraphs 3.4 and 3.5 (for soil and rock samples, respectively) of the standard ELOT EN ISO 1997-2. Acceptable types of sampling for the project are A and B.

The minimum percentage of core recovery in a sampling borehole is 90 % (sampling category in line with the above paragraph). In case the core recovery in a full sampling borehole is less than the minimum required, AM is entitled not to accept and pay for the subject borehole, and to instruct the Contractor to repeat the borehole at an adjacent location.

The volume and mass of each sample will be the ones required to properly perform the necessary laboratory tests described in para. 8 also according to the information in appendices L and T of Eurocode 7 (ELOT EN 1997-2)

The diameter of the samples will be adequate to properly perform the required laboratory tests of para. 8. Additionally, the minimum diameter of the samples will be 82 mm along the entire length of the boreholes. The Contractor is not entitled to any compensation for any increase in diameter that he decides to proceed for his convenience.

The core run will not exceed 1.5 m and the core barrel will be removed from the drilling hole as often as required in order to obtain the best possible sample (core). When core recovery is less than 90% of the full length of the drilling, then the core run of the subsequent drilling will be reduced to 1 m.

6.3 Mechanical equipment selection

The stipulations of para. 5.4 apply.

6.4 Selection of sampling method

The choice of sampling method is as per paragraphs 5, 6 and 7 of ELOT EN ISO 22475-1.

The Contractor shall justify in the Geotechnical Investigation Programme (para. 11.3.3.1) the choice of sampling methods in relation to the required sampling category, the required volume of the sample, and the required diameter of the sample, depending on the type of laboratory tests in accordance with the requirements herein.

6.5 Requirements before the start of works

6.5.1 General

The Contractor shall begin the execution of field geotechnical operations after approval of the Geotechnical Investigation Programme and relevant Material Submission Sheets (MSS) and after execution of all the prerequisite works in accordance with the requirements herein (e.g. drilling site fencing, obtaining approval of traffic diversions, installation of appropriate signage in accordance with the approved traffic arrangements, issuance of necessary permits from relevant agencies, cooperation with third parties, preparation of layout drawings with borehole positions, delivery of necessary machinery and auxiliary equipment such as setting tanks).

See also the contents of para. 5, ELOT EN ISO 22475-1.

6.5.2 Pre-excavation pits

The Contractor, prior to the execution of works, shall examine the extent to which the drilling about to be executed prevents the execution of other works or services or gives rise to problems at existing networks. In such cases, the Contractor shall timely communicate with the concerned agencies in order to inform them.

Prior to the commencement of any works, the Contractor shall obtain updated drawings from the responsible Public Utility Organizations (PUO) showing the networks and other installations, shall investigate the presence of networks on the basis of these drawings and on site evidence and finally shall communicate with the responsible PUOs in order to avert any risk to inflict damage on existing networks. The above drawings shall be submitted to AM in a digital form, once the respective field works are completed,

The Contractor, prior to the execution of any borehole, shall very carefully excavate the pre-excavation pit, using hand tools, depth of not less than 1.2 m, in order to check for the existence of underground services or networks. At the locations where PUO Networks may be at a depth greater than 1.2m, or where the expected PUO Networks have not been encountered, the Contractor will conduct further excavation, again without using mechanical means.

NOTE In order to detect underground PUO networks, the use of Cable Avoidance Tools-CAT is recommended.

NOTE If the Contractor has ruled out the possibility of encountering underground PUO networks, he may not excavate the pre-excavation pit after having advised AM accordingly.

For the entire excavation period, the Contractor shall maintain the pit free from water through pumping or other means.

Immediately after the completion of the excavation, plastic casing of a suitable diameter shall be placed running from the ground surface to the excavation bottom, serving as a guide to start drilling. This casing shall be secured in place using temporary or permanent backfill (see para. 6.14). The drilling rig is subsequently installed at the drilling location.

The positions, depths and dimensions of all PUO encountered networks, the final depth of the pre-excavation pit, as well as all required information concerning the pre-excavation pit shall be recorded in the Pre-excavation Pit Report. (see §11.5.2).

6.5.3 Trial pits

The execution of any trial pits to investigate ground conditions *in-situ*, sample recovery or execution of field tests and backfilling / compaction shall follow the stipulations in para. 6.5.2 herein.

6.6 Soil sampling methods

6.6.1 General

Soil sampling is based on the provisions of para. 6 of ELOT EN ISO 22475-1.

There are three sampling techniques:

- Continuous sampling during drilling
- Sampling using samplers
- Block sampling

6.6.2 Sampling categories

The sampling categories according to ELOT EN 1997-2 and ELOT EN ISO 22475-1 are three: A, B and C.

These three categories of sampling are associated with five quality classes of samples that can be recovered according to Table 9.1. These classes are determined each time by soil properties that are considered unchanged during sampling, handling, transportation and storage of samples, in relation to the requirements of any laboratory tests.

Samples of quality class 1 or 2 can only be obtained by using category A sampling methods. The intention during category A sampling is to obtain samples in which no or only slight disturbance of the soil structure has occurred during the sampling procedure or in handling of the samples. The water content and the void ratio of the soil correspond to that *in-situ*. In addition, no change in constituents or in the chemical composition of the soil has occurred.

Table 6.1 — Quality classes of soil samples for laboratory tests and the required sampling categories

Soil properties ↓ quality class →	**1**	**2**	**3**	**4**	**5**
Unchangeable soil properties					
Particle size	✓	✓	✓	✓	
Water content	✓	✓	✓		
Density, density index, permeability	✓	✓			
Compressibility, shear strength	✓				
Properties that can be determined					
Stratigraphy	✓	✓	✓	✓	✓
Boundaries of strata – broad	✓	✓	✓	✓	
Boundaries of strata – fine	✓	✓			
Atterberg limits, particle density, organic content	✓	✓	✓	✓	
Water content	✓	✓	✓		
Density, density index, porosity, permeability	✓	✓			
Compressibility, shear strength	✓				
Sampling category, per ELOT EN ISO 22475-1	A				
			B		
					C

By using category B sampling methods, this will preclude achieving sampling quality class 1 and 2. The intention is to obtain samples containing all the constituents of the *in-situ* soil in their original proportions and the soil has retained its natural water content. The general arrangement of the different soil strata or components can be identified. The structure of the soil has been disturbed.

The Contractor shall select the appropriate method for sampling, per case, in relation to the expected geological and hydrogeological conditions, so as to ensure minimal disturbance of samples so as to be able to execute the laboratory tests of Annex B herein and to make the engineering geological description of para. 8 herein. Examples of sampling methods in relation to different categories of soil sampling are given in Table 4 of the ELOT EN ISO 22475-1.

6.6.3 Sampling by drilling

The Contractor shall recover samples with rotary core drilling with a double or triple tube core barrel as per para. 6.3.2.2 of ELOT EN ISO 22475-1. Additionally, the inner sleeve shall be divisible in two along the axis (split inner tube) to avoid disturbance of the sample during removal from the core barrel. In the event that the Contractor wishes to use another method of continuous sampling, he shall submit the relevant justification to AM for approval, within the Geotechnical Investigation Programme.

According to the above, sampling is not permitted using a rotary single tube core barrel**,** since that kind of sampling normally provides samples of quality class 4. The use of single tube core barrel is only allowed in cases of cleaning of the borehole (removal of muck e.g. following casing, when restarting of drilling after an interruption, for the removal of tested geomaterial following an SPT), or in cases of loose gravel that can be sampled by no other core barrel. The flushing medium shall be clear water. Where required, and with the approval of AM, additives such as bentonite, biodegraded materials and other types of material can be used in order to improve viscosity.

Water supply during the drilling-sampling will be continuous and sufficient in order to achieve the optimum sampling according to the prescriptions described herein.

Sampling without using flushing medium or with a very low flow rate is not allowed, since such type of sampling normally falls into samples with quality class 4.

During drilling, temporary casings are used where the ground is or is expected to be unstable, contains cavities or where sampling is not satisfactory. In cases where casing is required, given the above, its advance will follow each drilling step at a short distance, not higher than 0,30 m.

The Contractor shall provide onsite all required temporary casing diameters and the required lengths for each diameter in order to achieve the minimum required sampling diameter for the entire length of the boreholes, as mentioned in para. 6.2 herein.

6.6.4 Sampling with samplers

The Contractor shall select the appropriate sampler (e.g. Shelby, Denison, Pitcher), as the case may be, in relation to the anticipated geological conditions, in order to ensure the minimum disturbance of the samples, according to the provisions of para. 6.4 of ELOT EN ISO 22475-1 standard.

The Contractor shall provide and use all the above types of samplers at all the drill sites that are required, per case.

The equipment of all types of samplers is submitted as part of the Geotechnical Investigation Programme.

6.6.5 Vessel samples

Small disturbed "vessel samples" are category B samples and are not less than 700 g. They are placed immediately in the appropriate airtight containers.

6.6.6 Block sampling from trial pits

Block sampling is executed based on the provisions of para. 6.5 of the ELOT EN ISO 22475-1 standard.

6.7 Rock sampling methods

6.7.1 General

Rock sampling is based on the provisions of para. 7 of the standard ELOT EN ISO 22475-1.

There are three sampling techniques:

- Sampling by drilling.
- Block sampling.
- Integral sampling.

6.7.2 Sampling categories

The sampling categories according to ELOT EN 1997-2 and ELOT EN ISO 22475-1 are three: A, B and C.

By using category A sampling methods, it is intended to obtain samples in which no or only slight disturbance of the rock structure has occurred during the sampling procedure of the samples. The strength and deformation properties, water content, density, porosity and the water permeability of the rock sample correspond to the in situ values. No change in constituents or in the chemical composition of the rock mass has occurred.

By using category B sampling methods, it is intended to obtain samples that contain all the constituents of the *in-situ* rock mass in their original proportions and the rock pieces have retained their strength and deformation properties, water content, density and porosity. By using category B sampling, the general arrangement of discontinuities in the rock mass can be identified. The structure of the rock mass has been disturbed and thereby the strength and deformation properties, water content, density, porosity and water permeability of the rock mass itself.

The Contractor shall select the appropriate method for sampling, per case, in relation to the expected geological and hydrogeological conditions, so as to ensure minimal disturbance of the geomaterial in order to execute the laboratory tests of para. 8herein and to make the engineering geological description of Annex B herein.

6.7.3 Sampling by drilling

The Contractor shall recover samples by rotary core drilling with a double or triple tube core barrel as per para. 7.3.3 of the ELOT EN ISO 22475-1 standard. Additionally, the inner sleeve shall be divisible in two along the axis (split inner tube) to avoid disturbance of the sample during removal from the core barrel.

According to the above, <u>sampling is not permitted using a rotary single tube core barrel,</u> since that kind of sampling normally provides samples of quality class 4. The use of single tube core barrel is only allowed in cases of cleaning of the borehole (removal of muck e.g. following casing, when restarting of drilling after an interruption, for the removal of tested geomaterial).

The flushing medium shall be clear water. Where required, and with the approval of AM, other flushing medium may be used such as mud, additives or foam.

Water supply during the drilling-sampling will be continuous and adequate in order to achieve the optimum sampling according to the prescriptions described herein.

Sampling without using flushing medium or with a very low flow rate is not allowed, since such type of sampling generally disturbs the sample.

During drilling, temporary casings are used where the ground is or is expected to be unstable, contains cavities or where sampling is not satisfactory. In cases where casing is required, given the above, its advance will follow each drilling step at a short distance, not higher than 0,30 m.

The Contractor shall provide onsite all required temporary casing diameters and the required lengths for each diameter in order to achieve the minimum required sampling diameter for the entire length of the boreholes, as mentioned in para. 6.2 herein.

6.7.4 Block sampling from trial pits

Block sampling is executed based on the provisions of para. 7.4 of ELOT EN ISO 22475-1.

6.8 Soil and groundwater sampling methods for conducting chemical analyses

6.8.1 Soil sampling for aggressivity tests

Obtaining soil samples includes the use of vessels compatible with the controlled chemical parameters (stainless vessels or vessels coated with TEFLON material) and with appropriate safety measures, held in sealed glass containers of 100-500 ml volume, the maintenance in a portable refrigerator at constant temperature of 4 °C in the field and the direct transfer directly to the chemical laboratory.

The soil samples are used in the execution of chemical analyses to determine aggressivity, as described in para. 8.4.3 herein.

6.8.2 Soil sampling for geochemical pollution detection

The strict requirements for sampling and preservation of soil samples (EPA-823-B-01-002) apply until transfer of samples to the laboratory for analysis, which must take place immediately.

The soil samples are used in the execution of the chemical analyses for the detection of geotechnical pollution of para. 8.4.4.

6.8.3 Groundwater sampling methods

Groundwater sampling follows the provisions of para. 8 of the ELOT EN ISO 22475-1.

The containers are thoroughly rinsed with demineralized water and are sealed before transportation to the sampling location. Three water samples will be taken per sampling location. Each sample will be no less than 0.5 litres. Before sampling, the container is thoroughly rinsed with groundwater for that area. The water sample is immediately transferred to the laboratory for (a) aggressivity tests according to the Concrete Technology Regulation and the provisions herein (para. 8.4.3) or (b) chemical analyses to determine geochemical contamination (para. 8.4.4).

At boreholes where more than one aquifer has been detected, separate samples are taken for each aquifer.

6.9 Drilling and sampling programme

Sampling shall be performed by the Contractor as follows:

6.9.1 Rock or rock mass drilling and sampling

- Category A continuous sampling with double tube core barrel with split inner tube.
- In the case of very poor rock mass, one sampling, category A, with triple tube core barrel and split inner tube for every 3m of drilling, or as instructed by AM on site.

6.9.2 Soil drilling and sampling

In soil, the first 1 m of the borehole (underneath the pre-excavation pit) shall be executed with category A or B sampling with double tube core barrel with split inner tube. Then, the following work cycle shall be applied:

- obtaining a small disturbed "vessel sample" from the core of the aforementioned sampling. A "vessel sample" shall be obtained every time that the soil formation changes,
- borehole cleaning,
- execution of Standard Penetration Test (SPT),
- borehole cleaning,
- category A or B sampling with a double tube core barrel and with the inner sleeve divisible in two (split inner tube) for 4 m.

NOTE In very soft and soft fine grained soils, category A sampling with a double tube core barrel and split inner tube or the appropriate sampler (e.g. Shelby, Denison, Pitcher samplers) shall be used.

This sampling cycle may change depending on the on-site conditions after having obtaining AM's consent.

6.9.3 Drilling and sampling in alternations of rocks or rock masses with soils

In the event of between rock or rockmass and soil, combined use of the above shall be made. In any case, for every layer of soil more than 2m thick, a Standard Penetration Test (SPT) shall be executed.

6.10 Groundwater level measurements during drilling

When groundwater is encountered during the drilling procedure, it is measured and recorded in the following manner:

- Water levels are recorded at the beginning and end of each shift, upon completion of the borehole to the required depth and prior to backfilling. Whenever groundwater is recorded, the depth of the boring, the length of casing inserted in the borehole and the time of measurement will also be recorded.
- In addition to the level, the Contractor shall record any other observations regarding the groundwater, e.g. artesianism, sudden groundwater inflow or loss during drilling, sudden rise or fall of the groundwater level, etc.

6.11 Measurement of the final length of the borehole drilling

As soon as the drilling is completed and before the installation of any type of instrument (e.g. piezometer), the Contractor shall measure the final length of the drilling in the presence of AM's representative, who shall have been notified on the previous day.

The overall length (depth) of the borehole to be measured is equal to the length deriving from the invert pre-excavation pit elevation (drilling commencement point) minus the borehole invest elevation. The final length of the borehole shall be measured along its axis with the drilling rods.

6.12 Piezometer installation

The type of piezometer shall be selected as per the requirements of ELOT EN ISO 22475-1 (see para. 12.1) and shall be documented in the Geotechnical Investigation Programme.

Piezometers shall be installed as per the requirements of Annex A herein. The piezometer tip shall be designed per para. 6.14 herein.

6.13 Backfilling of drill holes

In case piezometers are installed, the stipulations in para. 12.7 herein find application.

In the event no piezometer is installed, as well for the cases of non-sampling boreholes which must be backfilled, the hole shall be sealed with grout from the bottom to the surface by pouring through a tremie pipe the specified cement grout in compliance with para. 5.5 of ELOT EN ISO 22475-1. The grout properties shall be proposed by the

Contractor in the Geotechnical Investigation Programme.

When artesian conditions are encountered with flow of water from the borehole to the surface, the borehole is grouted to prevent the flow. This may require the use of additional casings, plugs and/or special grouts. Upon completion of works, no water leakage from the borehole should be observed.

6.14 Worksite area reinstatement

Immediately following the completion of the borehole drilling and the removal of the drilling rig and all other worksite installations, the pre-excavation pit is backfilled, as per the requirements in para. 5.5 of ELOT EN ISO 22475-1. The backfill shall be made of the appropriate materials in layers sufficiently compacted in order to avoid ground surface depressions due to settlements.

NOTE If the Contractor has temporarily backfilled the pre-excavation pit in order to secure in place the drilling guide (para. 6.5.2), then the Contractor shall remove the temporary backfilling materials, any water and any other materials in the pre-excavation pit before commencement of the final backfilling activities.

Subsequently, the area is reinstated to its original condition clean, free of any excavation spoil and liquid / solid wastes, according to AM's directions. If a piezometer has been installed in the borehole, its protective measures will also be constructed (see para. 12.7).

After the completion of the above works, the Contractor shall notify AM to inspect the area and, having obtained AM's concurrence, the worksite fencing is removed.

6.15 Topographical 'as built' survey

The Contractor carries out a survey of the site and locates all boreholes, trial pits and other investigation 'as built' locations.

Initially, the Contractor shall prepare a sketch showing the location of the 'as-built' borehole or pit with the location and the distances from three fixed objects shown on the drawings. This sketch is included in the Daily Borehole Sheet and in the respective Geotechnical Investigation Factual Report.

The Contractor also submits an 'as built' layout with all the locations of the boreholes and pits which is submitted in the Geotechnical Investigation Factual Report. The Project's (Thessaloniki Metro Development Plan - SAMTH) coordinate system shall be used. The precision of the survey for the location of boreholes is:

- Location (X & Y): ± 0.10 m.
- Elevation (Z): ± 0.01 m.

In addition, the Contractor shall provide a survey of the boreholes and pits in EGSA87 and WGS84 coordinate systems. The coordinates of the locations shall be submitted in a tabulated form, as part of the GI Factual Report.

6.16 Handling, transport and storage of samples

6.16.1 General

The handling, transport and storage of samples are carried out in compliance with the guidelines of chapter 11 of the standard ELOT EN ISO 22475-1 and the guidelines herein.

The Contractor is responsible for the packing, preservation and storing of all samples and their transport to the laboratory or places to be designated by AM. The Contractor is exclusively responsible for the safety and the good condition of the cores and samples. It is emphasised that poor management and protection of samples at all stages of work from drilling to the execution of laboratory tests, results in a significant deterioration in quality. <u>If in its reasonable and documented opinion AM ascertains, at</u>

any stage after sampling, loss of core samples or deterioration of their quality to the extent that the proper engineering-geological description and conduct of the lab tests is not permitted, then AM reserves the right to impose the stoppage of the relevant works and demand even the repetition of the drilling.

6.16.2 Recovery, field photographing and core preservation

Core barrels are held horizontally whilst cores are extruded. Core extraction is accomplished without vibration and in a manner to prevent disturbance of samples. Except where inner rigid tubes are used (e.g. Shelby, Denison, Pitcher samplers), the cores shall be extruded into rigid plastic receiving channels of a diameter slightly larger than the one of the cores.

Then, the core is placed in the middle of a wooden levelled base, with colour charts and depth indications and is photographed from a vertical position, so that the base may cover the visual field of the camera. The photos will be taken in compliance with the provisions of para. 10 herein.

Once photos are taken, the channel and the core are then wrapped in transparent polyethylene foil and secured with adhesive tape and shall be placed in the core box. Cores are carefully re-wrapped with transparent polyethylene foil every time after their description and/or after sample selection.

6.16.3 Core boxes

The construction of core boxes is carried out in compliance with para. 11.6 of ELOT EN ISO 22475-1 and the following guidelines.

Core boxes are soundly constructed of wood or other approved material fitted with partitions, stout carrying handles, fastenings and hinged lids. The core boxes shall be divided in three compartments each containing 1 m long core. The external dimensions of the boxes will be 1,05 m by 0,35 m by 0,12 m. The core boxes shall have smooth external surfaces (lid and base) for easy stacking. The total tare weight of each core box (full of cores) shall not exceed 50 kg and shall be subject to approval by AM.

Cores are placed in the core box with the shallowest core to the top left hand corner (the top being considered adjacent to the hinged lid). For every compartment, the shallower core is to the left. The cores are rigidly contained in the core box with rigid spacers (e.g. wood) indicating the limits of the core run. In case a void is encountered during drilling, two successive spacers shall be placed indicating the void's start and finish depths, designated with the word "void". Unused spaces within the cores are filled with appropriate material so as to secure the cores for their transportation.

At the outer and inner surface of the lid, the following shall be permanently marked:

- Project name.
- Borehole code.
- Box serial number associated with the total core boxes of the borehole.
- Depths (start-finish) of the cores contained in the core box.

On the three sides of the core box (front, left and right) the abovementioned information shall also be permanently marked with the exception of the Project name.

At the end of each day's work, core boxes are stored in an area secured from interference and protected against weather conditions.

6.16.4 Description of core samples, core photographing, selection of samples and transportation of samples to the laboratory

Following the completion of boreholes, photographs of the cores in the core boxes will be taken as well as a description of the cores and selection of samples for the execution of laboratory tests. The aforementioned works will take place in a sheltered area in compliance with para. 13.1 herein.

Core photographing procedure in the boxes will take place in compliance with the provisions of para. 10 herein.

The engineering geological description of cores will be carried out in compliance with Annex B.

The selection of samples is done in accordance with para. 8.2. After sample selection, they are packed according to the terms in para. 11.3 of the ELOT EN ISO 22475-1 and should be accompanied by an inscription, according to the prescriptions of para. 11.4 of the ELOT EN ISO 22475-1. Samples inside the tubes of the samplers bear similar inscriptions, which will be opened directly at the laboratory.

The packed samples are then transported to the laboratory of the Contractor, in accordance with the requirements of para. 11.5 of the ELOT EN ISO 22475-1.

6.16.5 Preservation and disposal of laboratory samples

All samples delivered to the Contractor's laboratory are kept for a period of one month after submission of the approved Factual Report and afterwards may be discarded only if agreed with AM.

6.16.6 Transport and storage of core boxes

Following the engineering geological description of and the selection of the samples for the execution of laboratory tests, the core boxes are carefully transported and delivered to a safe and protected location and they shall also be available for inspection by AM, whenever requested.

All core boxes are protected at all times during handling, transportation and storage against precipitation, sunlight, vibrations, freezing conditions and drying.

After approval of the relevant reports, and at a time that AM will determine, all core boxes will be transferred from the worksite facilities of the Project, and will be placed, classified by borehole and serial box number, to a specific storage location which will be indicated by AM. The transportation and placement of core boxes shall be made by personnel and equipment which shall be provided by the Contractor, and at the Contractor's expenses, in consultation with AM.

7 Specifications for geotechnical investigations – *In-situ* tests

7.1 General

The *in-situ* tests to be executed are generally the following:

- Standard Penetration Test (SPT)
- Cone Penetration Tests – CPT: Electrical Cone (CPT), Piezocone (CPTU), mechanical cone (CPTM)
- Pressumeter test
- Water Permeability Test: variable head (Maag), constant head (Lefranc) and packer test (Lugeon)
- Measurements of volatile organics
- Dynamic probing test
- Flexible dilatometer test
- Borehole jack test
- Flat dilatometer test
- Weight sounding test

7.2 Personnel to execute *in-situ* tests

All *in-situ* tests are carried out by trained personnel (see para. 5.1) who have gained experience in the use of the equipment, the test methods and the recording of results. The Standard Penetration Test (SPT) will generally be carried out by rig operators under the supervision of the Borehole Geologist. All the other *in-situ* tests shall be executed by experienced personnel. The personnel of the *in-situ* tests shall be submitted to AM for approval in the framework of the Geotechnical Investigation Programme (see paras. 11.3.3.1 and 11.3.3.2).

7.3 *In-situ* test equipment calibration

Where equipment is used in the execution of the tests, the Contractor has such instruments calibrated at intervals consistent with their usage and in compliance with the relevant specifications.

7.4 Continuous recording devices

Where pressuremeter and CPT tests are carried out, continuous recording equipment is provided to monitor the results as the test proceeds.

All the equipment is used in accordance with the manufacturer's recommendations to ensure that the readings obtained are true and accurate.

7.5 *In-situ* tests specifications and requirements

In-situ tests shall be executed in line with the following standards or equivalent.

7.5.1 Standard Penetration Test (SPT)

This test is carried out in accordance with ELOT EN ISO 22476-3.

7.5.2 Cone Penetration Tests (CPT)

These tests are carried out in accordance with ELOT EN ISO 22476-1 or ELOT EN ISO 22476-12.

7.5.3 Pressuremeter test

Pressuremeter testing is carried out in accordance with ELOT EN ISO 22476-4, ELOT EN ISO 22476-6 or ELOT EN ISO 22476-8, as well as with para. 4.4 of ELOT EN 1997-2.

7.5.4 Water permeability tests

The in-situ water permeability tests to be executed are the following:

1. Variable head test (Maag).
2. Constant head test (Lefranc).
3. Packer test (Lugeon).

The general rules governing the selection and execution of the permeability tests are given in ELOT EN ISO 22282-1. Test [1] and [2] shall be executed according to ELOT EN ISO 22282-2, while test [3] shall be executed according to ELOT EN ISO 22282-3.

Permeability tests are carried out at sampling boreholes during the drilling. In general, variable head tests are carried out. In case of high-permeability formation at which variable head test presents technical difficulties in its execution (rapid water level recovery), then, a constant head test is carried out.

Packer tests are executed on rock masses whose hydraulic properties mainly depend on their discontinuities. In addition to ELOT EN ISO 22282-3, the following requirements apply as regards the packer tests:

- The test will be carried out with appropriate packers, at steps to be defined *in-situ* based on the depth and the maximum head.

- The applied pressures will not exceed the 80 % of the corresponding earth pressure at the test location.

In addition to the respective standards, the following requirements apply as regards the aforementioned tests:

- The pump to be used for these tests should be a pump ensuring high water supply for efficiency of the test in high permeability units as well.
- In any case, clear water is exclusively used during the drilling so as not to affect the water permeability.

7.5.5 Measurements of volatile organic compounds

All boreholes will be checked for potentially contaminated soil which will include taking field measurements on the extracted drill cores, indicative of volatile organic compounds (VOC) using the PID device.

The measurements shall be made using the following procedure:

- The test samples (approximately 10 cm in length) will be selected immediately after extraction from the sampler and placed in transparent PVC one-use bags, which will be sealed quickly.
- After a period of 10-15 min a small hole will be opened using the 'nose' of the PID and the device will take the measurement while stirring the sample in order to facilitate the release of gases that may have been trapped in its mass.
- After the measurement the samples are placed in their position in the core box.

The requirements relating to the measurements are defined as follows:

- The measurements will be made on all sampling boreholes with soil or weathered rock materials. Typically, measurements shall be made on at least two (2) soil or weathered rock samples, taken from approximate depths of 0 to 10 m.
- If the measurement of the instrument in a sample exceeds 25 ppm, then the following measurements will be more frequent.
- Samples from greater depth will be used, if there is evidence or suspicion of organic pollution (odorous smell, striking colour tints, proximity to petrol station etc.).

7.5.6 Other *in-situ* tests

Dynamic probing tests, flexible dilatometer tests, borehole jack tests, weight sounding tests and flat dilatometer tests shall be executed in accordance with ELOT EN ISO 22476-2, 22476-5, 22476-7, 22476-10 and 22476-11, respectively.

7.6 *In-situ* test programme

The Contractor shall define the required i*n-situ* test programme, which is submitted as a part of the Geotechnical Investigation Programme (para. 11.3.3.1). In the subject Programme, the Contractor shall define the type of the *in-situ* tests he intends to execute, the methodology, the frequency and any other execution parameter per test.

The requirements applicable for the *in-situ* test programme are as follows:

- Pressure-meter test in specifically drilled borehole: the content of §6.1 applies.
- Standard Penetration Test (SPT): the test execution frequency at the sampling boreholes is specified in para. 6.9.2.
- Cone Penetration Test (CPT): the content of para. 6.1 applies.
- *In-situ* permeability tests in boreholes:
  - permeability tests shall be executed in all sampling boreholes.
  - executed permeability tests shall cover all geological formations encountered in the Project. Special attention shall be given so as to ensure execution of an

adequate number of permeability tests in the event of great thickness superficial artificial deposits and high-permeability units.

- In general, one permeability test every 6 m of drilling shall be executed.
- In tunnel areas, three (3) out of the above-mentioned tests shall be executed as follows: one test inside the tunnel cross-section, one test at the zone situated 3m above the tunnel crown and one test at the zone situated 3 m under the tunnel invert.
- a permeability test shall be executed in case a high-permeability formation is encountered or in case of sudden water inflow in the tunnel or of sudden water loss in the borehole.

7.7 Data to be submitted

The *in-situ* test results are recorded as described in the requirements of the standard governing their execution.

All the results of the *in-situ* tests are submitted in a hard copy and in an electronic format in compliance with the AGS Standard, as specified in Annex E herein.

The data submitted by the Contractor shall include the following, as appropriate:

- Calibration charts for all the instruments used.
- Records of calibration checks made in the field before, during and after the test.
- Copies of original field data sheets and, where continuous recording devices are used, copies of chart records or printouts from data loggers.
- Calculation sheets showing the analysis of the results and the parameters obtained from each test. Where computer carries out calculations, then copies of the computer output will be accepted, as long as the computer programme has been previously approved.

All the above are submitted as part of the GI Factual Report (para. 11.6.2), with the exception of the measurement of the Volatile Organics (para 7.5.5), which shall be submitted together with the Geological Design (para. 11.6.1).

8 Specifications for geotechnical investigations – Laboratory tests

8.1 Laboratories

Soil and rock mechanics laboratory tests shall be executed at the laboratory(-ies) stated in the Contractor's Offer, based on the requirements of para. 20.2.2b of the *Invitation*. More precisely, <u>the tests specified in para. 20.2.2b of the *Invitation* shall be executed only at the laboratories stated in the Contractor's offer which are holding the relevant permit or accreditation for such tests</u>. In addition, if it is necessary to execute tests which might not be executed at the laboratory(-ies) stated in the Contractor's offer, the Contractor shall see to their execution in other recognized laboratories which will be submitted for approval by AM in the framework of the Geotechnical Investigation Programme or later on though a letter transmitted to AM.

8.2 Selection of samples – Laboratory Test Programme Tables

After the completion of each borehole or group of sampling boreholes, the Contractor notifies AM in order to carry out the engineering geological description of borehole cores. It is emphasized that the time period between the completion of the borehole, the engineering geological description and selection of the samples must be the shortest possible, so as to avoid sample disturbance (e.g., drying during summer months). The Contractor shall transmit an e-mail message to AM, specifying the date of the engineering geological description and sample selection, as well as the code numbers of all boreholes. Moreover, the Contractor shall transmit an e-mail to AM with the Preliminary Laboratory Test Programme Tables for each borehole. The lab test programme shall be drafted as described in para. 8.4, taking into account all data from the borehole Daily Works Sheets.

A similar procedure shall be followed for *in-situ* engineering geological description and selection of samples from trial pits, after communication with AM.

Then follows the engineering geological description and the sample selection for the execution of laboratory tests, in the presence of AM.

The Contractor, after the completion of each borehole, prepares the Proposed Laboratory Test Programme separately for each borehole. The Tables for all boreholes shall be transmitted via e-mail to AM the latest on the day after the sample selection. If the Contractor does not receive a response until the next working day, then he can execute the tests according to his proposed programme.

The final Proposed Laboratory Test Programme Tables along with the Executed Laboratory Test Programme Tables (tables listing the executed lab tests) are submitted as part of the GI Factual Report (para. 11.6.2).

The Laboratory Test Programme Table shall be a standardized report and shall include the following information:

- Code of borehole or trial pit.
- Sample selection date.
- No. of sample.
- Sample depth (from/to) (from borehole).
- Location and dimensions of sample (from trial pit).
- Sample type (from core sampling, sampler type, vessel).
- Type of proposed tests.
- Name and signature of Head of Laboratory.

8.3 Specifications for the execution of laboratory tests

Table 8.1 lists the foreseen laboratory tests and their respective standards governing their execution. The Contractor shall carry out the laboratory tests in accordance with the respective standards in Table 8.1, or other equivalent standard.

Table 8.1 — Foreseen laboratory tests and execution standards

No.	Test	Test execution standard
	Soil tests	
T1	Dry preparation of soil sample for laboratory tests [1]	E105-86
T2	Determination of water content	ELOT EN ISO 17892-1
T3	Determination of bulk density	ELOT EN ISO 17892-2
T4	Determination of particle density	ELOT EN ISO 17892-3
T5	Determination of liquid limit and plastic limit (Atterberg limits)	ELOT EN ISO 17892-12
T6	Determination of particle size distribution – sieving [2]	ELOT EN ISO 17892-4
T7	Determination of particle size distribution – sieving – determination of fines [2]	ELOT EN ISO 17892-4
T8	Determination of particle size distribution – hydrometer or pipette	ELOT EN ISO 17892-4
T9	Organic matter in soils using dry combustion	ASTM D 2974
T10	Determination of organic matter in soils by wet combustion	AASHTO T 194
T11	Determination of calcium carbonate content	BS 1377-3 Clause 6
T12	Water content – soil density relation (standard or modified PROCTOR)	ELOT EN 13286
T13	Californian ratio of bearing capacity (CBR)	ELOT EN 13286-47

No.	Test	Test execution standard
T14	Determination of maximum and minimum dry densities for granular soils	BS 1377-4
T15	Unconfined compression test	ELOT EN ISO 17892-7
T16	Unconsolidated undrained triaxial test (UU)	ELOT EN ISO 17892-8
T17	Consolidated triaxial test on water saturated soils – undrained conditions (with pore water pressure measurement, CUPP)	ELOT EN ISO 17892-9
T18	Consolidated triaxial test on water saturated soils – drained conditions (CD)	ELOT EN ISO 17892-9
T19	Direct shear tests – without consolidation	ELOT CEN ISO/TS 17892-10
T20	Direct shear tests – with consolidation (undrained)	ELOT CEN ISO/TS 17892-10
T21	Direct shear tests – with consolidation (drained)	ELOT CEN ISO/TS 17892-10
T22	Direct shear tests – Determination of residual shear strength in shear test apparatus	ELOT CEN ISO/TS 17892-10
T23	Direct shear tests – Determination of residual shear strength in ring shear apparatus	ELOT CEN ISO/TS 17892-10
T24	Incremental loading oedometer test	ELOT EN ISO 17892-5
T25	Incremental loading oedometer test – controlled loading rate	ELOT EN ISO 17892-5
T26	Incremental loading oedometer test – swelling test	ELOT EN ISO 17892-5
	Rock tests	
T27	Preparation of cylindrical rock sample [3]	See NOTE 3
T28	Rock water content	E103-84
T29	Porosity & density	E103-84
T30	Unconfined compression strength	E103-84
T31	UCS with *E* and Poisson ratio *v* readings	ASTM D7012
T32	Point load strength	E103-84
T33	Triaxial compression strength	E103-84
T34	Hardness using SCHMIDT hammer (L)	E103-84
T35	Shear strength of natural and artificial discontinuities	ISRM suggested methods or ASTM D 5607
T36	Slake durability index	ISRM suggested methods or ASTM D4644
T37	Indirect tensile strength (Brazilian test)	ISRM suggested methods
T38	C.E.R.CHAR. Abrasiveness Test	ASTM D 7625
	Mineral composition analyses	
T39	Mineral analysis with XRD method	
T40	Petrographic analysis [4]	
	Aggressivity of soil and groundwater and Geochemical pollution detection tests	
T41	Soil sampling for chemical analyses	See para. 6.8.1 or 6.8.2
T42	Determination of sulphates and ions content	ELOT EN 196-2
T43	Determination of soil content in chlorides	BS 1377-3 Subclauses 7.2, 7.3
T44	Determination of acidity degree in soil sample – pH	ELOT EN 16502
T45	Preparation of soil solution	DIN 38414-4
T46	TPH	EPA 8015b APHA 5520-C
T47	Water sampling and transportation to the laboratory for analysis	See para. 6.8.3
T48	Water chemical analysis	See NOTE 5
T49	Trace elements in water	–

NOTE 1 Detailed information regarding soil samples preparation is found in Appendix L of ELOT EN 1997-2.

NOTE 2 The particle size analysis is performed with sieves in accordance with standards ISO 3310-1 and ISO 3310-2, as well as in accordance with para. 18.10.2.

NOTE 3 Detailed information regarding rock samples preparation is found in Appendix T of ELOT EN

1997-2.

NOTE 4 Petrographic analysis shall include the requirements expressed in para.9.3.9.

NOTE 5 Water chemical analyses shall determine the following chemical properties on the basis of the respective standards (in parentheses):

- SO_4^{-2} (mg/l) (ELOT EN 196-2).
- pH (ISO 4316).
- Corrosive CO_2 (mg/l) (ELOT EN 13577).
- NH_4^{+} (mg/l) (ISO 7150-1).
- Mg^{+2} (mg/l) (ISO 7980).
- Cl^{-} (mg/l) (ISO 7393).

Whenever a laboratory test is executed on the basis of a standard not included in those listed in Table 8.1, this shall be an internationally recognized standard and the Contractor shall submit in the Geotechnical Investigation Programme (11.3.3.1) the proper documentation concerning the applicability of that specific standard to the specific ground formation and the specific geotechnical conditions, as per the stipulation in para 2.1 of ELOT EN 1997-2:2007/NA.

As regards the test in Table 8.1, for which there is no reference to an execution standard (T39, T40, T49), the Contractor shall submit –as part of the Geotechnical Investigation Programme (para. 11.3.3.1)– the relevant standards or internationally accepted methods based on which these tests shall be executed.

Those laboratory tests the Contractor intends to execute but are not included in Table 8.1, shall be carried out on the basis of an internationally recognized standard which shall be submitted by the Contractor as part of the Geotechnical Investigation Programme (para. 11.3.3.1).

8.4 Laboratory Test Programme

The lab tests are scheduled according to the design requirements of the subject Project.

The general guidelines and minimum requirements with regard to the programme and the quantities of the laboratory tests for soil, rock and water samples are presented below.

For each test, the numbering of the respective test of Table 8.1 is given in parentheses. The tests listed in Table 11.1 for which no guidelines are given in this paragraph shall be programmed on a per-case basis upon communication and agreement with AM. AM may request the execution of other tests beyond those specified in Table 8.1, as per its reasonable and documented judgement.

The laboratory test programme shall be included in the Geotechnical Investigation Programme (para. 11.3.3.1).

8.4.1 Soil samples

8.4.1.1 Physical properties tests

- Determination of water content, bulk density, particle density, Atterberg limits and particle size distribution (T1, T2, T3, T4, T5, T6, T7 and T8): one test every 3m. Atterberg limits (T5) and particle size distribution with hydrometer or pipette tests (T8) will be executed, when following particle size distribution with sieves, the fine fraction is higher than 5 %.
- Water content test (T2) will also be executed on "vessel samples".
- Organic matter on soils test (T9 or T10) will be executed on organics soils (see para. 18.10.2.1)
- Calcium carbonate content tests (T11) will be executed on carbonate soils (see para 18.10.2.1).

- From the results of the tests, the Plasticity Index I_P, the Liquidity Index I_L, the Consistency Index I_C and the Activity Index I_A will be estimated. For coarse grained soil which contain less than 10 % fines and less than 10 % gravel, the Density Index I_D can also be determined (T14). The description of consistency and density shall be based on these indices, as per para. 13.3.2 herein.
- The soil-like zones within the rock mass constitute a special case. As regards these zones, the water content, the Atterberg limits and the particle size distribution (T1, T2, T5, T6, T7 and T8) must be determined.

NOTE The results of these tests are necessary for the evaluation of the geomaterials in case of TBM excavation.

8.4.1.2 Mechanical properties tests

- Every 3 m of borehole, a sample shall be obtained for the execution of mechanical properties tests as follows: tests from the following two groups of tests shall be executed alternately.
  - 1st group: unconfined compression test (T15), unconsolidated undrained triaxial test (T16), unconsolidated undrained shear test (T19) with determination of the residual shear strength (T22) or without it.
  - 2nd group: consolidated triaxial test on water saturated soils (T17 or T18), consolidated direct shear test (T20, T21) with determination of the residual shear strength (T22) or without it.
- Two one-dimensional consolidation tests (T24 or T25) with swelling test (T26) or without it shall be carried out per borehole.

8.4.1.3 Mineral analyses

- Mineral analysis XRD (T39): it shall be programmed in the following cases (a) in soils where swelling minerals, such as montmorillonite, kaolinite, anhydrite etc. are likely to be encountered, (b) when during the execution of the swelling test (T26) high swelling tendencies are noted (c) in soils with a potentially high percentage of quartz (e.g. quartzitic sand).

NOTE The results of these tests shall be presented in the Geological Design. (§11.6.1).

8.4.2 Rock samples

8.4.2.1 Physical properties testing

- One water content test (T28), porosity and density test (T29) every 6 m of borehole.

8.4.2.2 Mechanical properties testing

- One unconfined compression strength with elastic modulus and Poisson ratio determination (T31) and two point load tests (T32) (one axial and one diametrical) every 3m.
- One triaxial compression strength test (T33) every 5m in intact rock samples consisting of rock masses with infrequent and rare discontinuities.
- One C.E.R.CHAR. abrasiveness test (T38) every 5m.
- Shear strength discontinuities tests (T35) shall be normally carried out in samples of characteristic natural discontinuities.

8.4.2.3 Mineral and petrographical analyses

- Petrographic sample analysis (T40) and mineral analysis XRD (T39): A sufficient number of analyses shall be scheduled for each case and depending on the encountered geological conditions in order to determine the petrographic types of the encountered units. A general rule is to conduct at least two petrographical analyses for each formation that can be macroscopically verified, while the XRD mineral analysis shall be scheduled, depending on the case.

8.4.3 Aggressivity of soil and groundwater

Specifically to determine basic design parameters, regarding the permanent works of reinforced concrete, sampling and testing according to the Concrete Technology Regulation (Appendix ΠΒ2) are required.

Aggressivity parameters that have to be checked are:

a. on soil samples:
- Acidity degree (ml/kg) per Baumann – Gully (T44)
- shulphates SO_4^{-2} (mg/kg) (T42)

b. on groundwater samples (T48):
- Sulphates SO_4^{-2} (mg/l)
- pH
- CO_2 (mg/l)
- Cations NH_4^+ (mg/l)
- Cations Mg^{+2} (mg/l)
- Chlorions Cl^- (mg/l)

Initially, tests T42, T44 and T48 are required to be carried out (on soil and water samples, respectively) as follows:

- For stations and shafts: at two depths per location (e.g. -10 m and -20 m).
- For tunnels: at 2 depths per location (e.g. 1 at the middle of the tunnel overburden and 1 at the depth of the tunnel axis).
- For bases: at 2 depths per location (e.g. -10 and -20m).

If defective values and/or striking deviations of the values are identified at some area, additional sampling is required, to ensure that dependable conclusions can be drawn.

NOTE The results of these tests shall be presented in the Geological Design (para. 11.6.1).

8.4.4 Geochemical pollution detection

At boreholes suspected to suffer pollution (e.g. boreholes adjacent to gas stations) or where there is such evidence obtained from PID measurements, soil and water samples shall be taken in order to conduct tests for determining petroleum hydrocarbonates (TPH), (T45 & T46 for soil, T47 for water).

The Contractor shall propose any other required test, so as to draw credible conclusions about geochemical pollution (see also standard BS 10175).

The full analytical results shall be evaluated based on the maximum permissible values (action values) set by the Environmental Protection Agency of USA, and, the most commonly used in Europe, Netherlands Dutch List, in conjunction with the relevant provisions of the Greek Legislation. If determined prices are below the limit values, the control of organic pollution is completed at this stage, without finding a particular pollution problem. Otherwise, the Contractor shall propose the arrangements required for further investigation.

NOTE The results of these tests shall be presented in the Geological Design (para. 11.6.1).

8.5 Submittal of laboratory test results

All the results of the laboratory tests are recorded based on the standard according to which they are executed, taking also into account the general requirements presented in chapter 5 of ELOT EN 1997-2.

The information submitted by the Contractor shall include the following, as required:

- Copies of original laboratory data sheets and, where continuous recording devices are used, copies of chart records or printouts from data loggers.
- Calculation sheets showing the analysis of the results and the parameters obtained

from each test. Where computer carries out the calculations, then copies of the computer output will be acceptable together with verification of the computer program.

- Especially as far as uniaxial strength tests are concerned, the following data will always be included in the laboratory test sheet: (a) lithological type of the sample (phase 3 of the engineering geological description, see para. 13.1), (b) report on the isotropy or anisotropy of the sample and in the case of anisotropy, record of the angle of the dominating bedding, foliation, schistocity etc., with the loading axis and (c) angle of the specimen fracturing surface with the loading axis.

All the above are submitted in printouts and soft copies (as per standard AGS, as specified in Annex E) as part of the Geotechnical Investigation Factual Report (para. 11.6.2), with the exception of the chemical water analyses (para 8.4.3), mineralogical and petrographical analyses (para 8.4.1.3 and 8.4.2.3) and geochemical pollution tests (8.4.4) which shall be submitted with the Geological Design.

9 Specifications for geological investigations

9.1 Requirements for geological investigations

The geological investigations are set in the scope of every individual contract and in the Project's design requirements, while their results are presented in the Geological Design, in the Geological, Hydrogeological, Geotechnical Longitudinal Section and Cross Sections.

Geological investigations shall be carried out within a zone of 350 m on both sides of the "Project's axis", which shall be extended for 350 m from the ends of the Project; these investigations shall be carried out in accordance with the applicable specifications and the requirements in this document.

9.2 Geological Investigation Programme

The Contractor shall submit a Geological Investigation Programme (see para. 11.3.3.2) where he shall propose and justify the geological investigations he is willing to conduct, in order to prepare the Geological Design and to provide the required geological data for the preparation of the Geotechnical Investigation Factual Report and the Evaluation Report of Geotechnical Investigation Results, as well as of the Geological, Hydrogeological, Geotechnical Longitudinal Section and Cross Sections.

9.3 Geological works

9.3.1 Geological mapping – Compilation of Engineering Geological Map

The Contractor shall carry out a geological mapping in the zone defined in para. 9.1.

The Engineering Geological Map shall be at a scale of 1:2000 and shall be compiled taking into account the requirements of the specification E 104-85. The map shall clearly show outcrops of the geological formations –or where feasible of the engineering geological formations– (see para. 11.6.3.2).

The outcrops shall be properly photographed so as to depict the structure of the geological formations, their contacts and other information, depending on the case.

9.3.2 Geological longitudinal section

A separate geological longitudinal section will not be prepared. The necessary geological data are integrated in the Geological, Hydrogeological, Geotechnical Longitudinal Section (see para. 11.6.3.5).

9.3.3 Geological cross sections

The provisions of para. 9.3.2 apply.

9.3.4 Recording of locations of earlier ground investigations and of water occurrence points

The Contractor shall record the locations where earlier ground investigations were conducted and the location where water is present within the zone defined in para. 9.1, as per the following paragraph.

The recording of locations where earlier ground investigations were conducted (sampling boreholes, wells, pits, galleries, geophysical investigations, etc.) shall include: (a) general information (execution entity and time, coordinates, etc.), (b) engineering geological description and test results, (c) installed instruments, (d) groundwater level measurements, (e) general observations and (f) documentation with photographs.

The recording of the locations with water occurrence (springs, wells, pumping wells) shall include: (a) general information (location, coordinates, ownership status, etc.), (b) technical data (depth, diameter, casing, pump, etc.), (c) hydraulic data (level, flow rate, etc.), (d) land use details, (e) geological data and (f) documentation with photographs.

Recording of works carried out during earlier ground investigations shall be presented in the Desk Study Report (see para. 11.3.2).

9.3.5 Groundwater level measurement

The Contractor shall carry out groundwater level measurements: (a) on the piezometers of this Framework Agreement, (b) on the piezometers of earlier geotechnical investigations to be made available by AM and (c) on the additional piezometers or observation wells or pumping wells the Contractor will discover (see para. 9.3.4) within the zone defined in para. 9.1.

NOTE At the time of delivery of the earlier installed piezometers, the Contractor shall initially verify their operational status and shall take steps for their cleaning and development by air-lift as necessary.

Groundwater level measurements shall be taken as per the stipulations in para. 10 of ELOT EN 22475-1.

The measurements shall commence immediately –upon availability of the measurement location– shall be taken at a frequency of at least one measurement per week and shall be submitted in the Geological Design (see para. 11.6.1).

9.3.6 Tectonic diagrams – Potential slides

The Contractor shall record the discontinuities at outcrops of rock masses within the zone defined in 9.1, taking also into consideration the requirements expressed in para. 1.5 (a) of standard E 104-85. The investigation and selection of the locations of these outcrops shall be such as to permit the collection of tectonic data for the engineering geological units expected to be encountered at a specific section of the Project for which tectonic diagrams of potential slides must necessarily be compiled further to AM's relevant suggestion.

Discontinuities recording includes the measurement of all geometrical data of the rock mass discontinuities (inclination, direction, persistence, spacing, aperture, filling material, etc.), presentation of same in a tabulated form, statistical processing of the data and compilation of the necessary stereographic projections (Schmidt net).

The above tectonic diagrams shall refer to specific section of the Project and shall be compiled with reference to their geometrical data, in order to determine the potential slides. If and where feasible, information about the friction angles of the discontinuities shall be also presented.

9.3.7 Geological mapping of slopes

The Contractor shall investigate the presence of artificial or natural slopes within the zone defined in para. 9.1, taking also into consideration the requirements expressed in para. 1.5 (c) of standard E 104-85. If such slopes are present and made up of engineering geological units that may be encountered in the Project, the Contractor shall perform geological mapping.

For this task, the following specifications are valid:

- Geological mapping of slope shall be made on a drawing under scale ranging from 1:20 to 1:200, depending on the slope dimensions.
- The drawing shall record the basic dimensions of the slope (length and height at specific locations).
- The drawing shall include an appropriate layout plan showing the location of the slope and the direction of recording.
- Geological units shall be recorded (using different colour schemes or symbols), so will contacts of geological units and their type (unconformity, normal transition, fault, thrust etc.) and the structure of the units (bedding, folds, etc.).
- For each geological unit identified on the slope, there will be an engineering geological description, as per Annex B, which shall be presented in the legend of the drawing.
- Measurements shall be taken for the orientation of the structural elements (contacts, bedding, foliation etc.) / tectonic elements (joint, fault, cleavage, axial and axis of fold etc.) / discontinuities, so as to record as detailed as possible the slope's structure. These measurements shall be presented on the drawing in the form of Schmidt net stereographic projections and/or rose diagrams.
- Geological mapping shall be accompanied by proper photographic documentation, as follows:
  - Overview.
  - Overlapping photographs.
  - Large scale details (close-ups) to show the lithology structure of the units, etc.

9.3.8 Rock mass classification

The Contractor shall perform rock mass classification GSI (Annex C) on all rock cores of the sampling boreholes, during phase 2 of the engineering geological description of the cores (see Annex B), as well as on appropriate natural or artificial slopes (see para 9.3.7). The classification of the rock mass for borehole cores is recorded in the Borehole Log (para. 11.6.2.1).

9.3.9 Petrographical and mineral analyses

These analyses shall be carried out on samples of borehole core, as per the stipulations in paragraphs 8.4.1.3 and 8.4.2.3.

The petrographical analysis recording report shall include:

- Determination of the mineral composition with microscopic analysis.
- Description of the main, secondary and supplementary minerals.
- Frequency of occurrence of minerals (%).
- Microscopic description of the rock texture.
- Determination of the petrographic type.
- Representative colour microscope pictures, showing the rock texture (each photo shall be taken with parallel and vertical Nicols).
- Photo of the specimen (cube) from which the thin slice was taken from.
- Photo of the original sample from which the thin slice was taken from, showing the location of the slice.

After the completion of the tests, the slices and the associated cubes shall be delivered to AM.

9.3.10 Engineering Geological Map

See paragraph 9.3.1.

9.3.11 Hydrolithological – Hydrogeological Map

The Contractor shall compile the Hydrolithological – Hydrogeological Map of the area defined in para. 9.1. This map shall incorporate at least the following: (a) hydrolithological formations (classification depending on the permeability of the engineering geological formations and type of their porosity), (b) the location of water occurrence (para. 9.3.4) and (c) the isopiezometric curves for maximum and high groundwater levels (see paragraphs 2.2.2 and 2.2.19).

The maximum and high groundwater levels shall be defined in accordance with the requirements expressed in para. 3.6.3 of ELOT EN 1997-2.

9.3.12 Other thematic maps

Other special or thematic maps shall be prepared further to the relevant proposal of the Contractor to be included in the Geological Investigations Programme (para. 11.3.3.2) and AM's approval.

9.3.13 Geological works in sampling boreholes

In addition to the works specified in paras. 9.3.8 and 9.3.15, geological works also include the engineering geological description of drilled units (Annex B) and the compilation of the Borehole Log (para. 11.6.2.1).

9.3.14 Pumping tests

Pumping tests shall be conducted according to ELOT EN ISO 22282-4. The Contractor shall submit to AM for approval Pumping Tests Methodology as part of the Geological Investigations Programme (see para. 11.3.3.2).

In addition to the stipulations in standard ELOT EN ISO 22282-4, the following requirements also apply with regard to the planning of the pumping tests:

- Pumping tests shall be conducted in order to determine the hydraulic parameters k, T and S of the groundwater table. To this end, a constant rate pumping test shall be carried out (see para. 5.5.4 of ELOT EN ISO 22282-4).
- Testing shall be conducted at a pumping well (test well) constructed specially for this purpose. Groundwater table level fluctuation shall be monitored both at the test well and also at the piezometers.
- The drilling of the test well does not require full sampling. In case where the test well is not drilled with sampling method, the nearest piezometer shall be installed in a sampling borehole.
- In order to minimize the construction of additional piezometers, already constructed piezometers shall be used where feasible.
- If the construction of additional piezometers is required, these shall be installed, depending on the case, in sampling or non-sampling boreholes, as required by the planning of the pumping tests, after AM's concurrence.
- The results of the pumping tests shall be evaluated on the basis of internationally recognized methods (e.g. Cooper & Jacob method, Dupuit / Thiem method, Theis method, see for reference appendix C of standard ELOT EN ISO 22282-4) in order to determine the water Table's hydraulic parameters *k*, *T* and *S*.

9.3.15 Rock Quality Designation – RQD

The Contractor shall determine the rock quality designation RQD (para. 13.2.10) on all rock cores of the sampling boreholes, during phase 1 of the engineering geological description of the cores (para. 13.1), taking into account the requirements expressed in para. 1.5 (b) of E 104-85. The RQD is recorded in the Borehole Log (para.11.6.2.1).

9.3.16 Chemical analyses on groundwater and soil

See paras. 8.4.3 and 8.4.4.

10 Photographic archive

The Contractor will perform detailed photographing of the works. Digital pictures will be taken from the rig worksites, pre-excavation pits and trial pits, the core runs of the samplers, the core boxes, the samples for laboratory testing, the locations of geological geo-physical works, etc.

10.1 Photographs' specifications

All photographs will be digital, full colour, minimum resolution is 15 megapixel, ¾ height/width ratio, in JPEG format, of high quality, low compression, 32 million colours, 24 bits per pixel with camera sensor at least APS–C/H (>300 mm^2).

The time and the date that the photograph was taken shall appear on each photograph, while the photograph shall also include on a per case basis the appropriate item as length scale (tape measure, scale meter, coin, etc.). Where required, the photograph shall also include a colour control patch (colour scale). When the shooting light conditions are different, there will be white or grey and/or neutral colour correction.

Each photograph shall contain sufficient information to locate the samples (e.g. borehole number and depth shall be recorded on sample photos, while the data referred to in para. 10.3 of this article shall be recorded on the borehole core photos, and on the photographs of the geological works, detailed data shall be provided for map tracing).

10.2 Photographs of boreholes, pre-excavation pits and investigation trenches locations

Photographs are taken to provide a fully detailed record of all site drillings and pre-excavation pits. Photographs of all four slopes and the bottom shall be taken from the investigation trenches. Site photographs will be submitted only in electronic form.

10.3 Photographs of borehole cores

The Contractor takes photographs to provide a fully detailed record of all borehole cores. Colour control patches (colour scale) and length scale to be included in each photo.

The cores are photographed twice:

- The first set of photographs (per core run) is taken as soon as the cores are extracted from the core barrel. These shall be submitted only in electronic form.
- The second set of photographs (per core box) is taken later when the cores are fully unwrapped and prior their engineering geological description and samples' selection for testing (see para. 13.1, phase 2). These shall be submitted in electronic form as well as in printed form.

When core boxes are photographed, attention shall be given to the uniform lighting of all boxes. In this case, apart from white or grey colour correction, there will also be colour balance correction/adjustment using a colour control patch and the appropriate software, so that colour and brightness rendering is the same for all photographs of this session, to the extend this is feasible.

The hard copy is presented in A4 size pages as follows: Each sheet shall successively include the photographs of five consecutive boxes (only the section including the cores with no cover). Special attention shall be paid to the following: (a) the widths of each photograph should be the same, (b) the photographs should not be distorted and (c) each photograph should also include the length scale and the colour control patches on its sides.

On the top of the sheet, the drilling code shall be recorded as well as the limits of the core depths shown on the said sheet. At the bottom of the sheet the page number will be referred as well as the total number of pages for each drilling. These A4 sheets shall be printed on photo quality paper at a minimum resolution of 300 dpi in colour, and shall be submitted as part of the GI Factual Report (para. 11.6.2).

10.4 Laboratory test specimens photographs

The Contractor shall take sets of photographs of all specimens (before and after the test) to create a full test archive. Rock specimens are cleaned and lightly sprayed with water prior to photographing to reveal structure and bedding.

Especially for sample photographs depicting petrographic analyses, the stipulations of para. 9.3.9 herein applies.

The photographs of the specimens will be submitted only electronically (see Annex E).

11 Submittals

11.1 General – Submission and submission review procedures

For each Individual Contract and prior to the commencement of the investigations, the Contractor shall submit for approval the *Ground Investigation Programme* (as per Eurocode 7) where he shall describe the proposed geotechnical (*Geotechnical Investigation Programme*) and geological investigations (*Geological Investigation Programme*) respectively (as specified in the scope of each Individual Contract).

All the results of the investigations shall be included in the <u>Ground Investigation Report</u> (as per Eurocode 7). This report shall consist of separate parts, which will be submitted as follows: initially, prior to the commencement of the investigations and as required from the corresponding Individual Contract, the Contractor shall submit for approval the Desk Study. Upon completion of the geotechnical investigations of each Individual Contract, the Contractor shall submit for approval the Geotechnical Investigation Factual Reports and once they are approved – and if required by the relevant Individual Contract – he shall submit for approval the corresponding Geotechnical Investigation Evaluation Report. Respectively, with regard to geological investigations – if such investigations are foreseen in each Individual Contract – upon their completion, the Contractor shall submit for approval the Geological Study.

In addition to the above basic submissions, the Contractor shall submit reports, sheets, programmes, etc. All the submissions of the Contractor shall be prepared in line with the provisions of the following paragraphs.

The submissions of para. 11.2 shall be made immediately upon the signing of the Framework Agreement and concern the entire Project. The submissions of paragraphs 11.3, 11.4, 11.5 and 11.6 shall be made on a per case basis, as required by each Individual Contract and the works executed each time.

All submittals shall be in Greek, which is the official language of the Tender. The submittals of the Ground Investigation Report (specified in paragraphs 11.3.2, 11.6.1, 11.6.2 and 11.6.3 with all their attached Logs and Forms) shall be also drafted in English. The English version shall be submitted once the official Greek version has been approved.

At its own reasonable and well-documented judgment and based on the findings of the on going investigations, the onsite conditions etc., AM may request additional information / data or differentiations to the content of the submittals specified in paragraphs 11.2 to 11.6.

11.1.1 Form and copies of submissions

The copies required for each submission are the following:

- The documents and drawings of the submissions specified in paragraphs 11.2, 11.3, 11.4 and 11.6 shall be submitted in four (4) coloured copies. The above shall be also submitted in electronic form (CD or DVD) in two (2) copies. All the copies of the documents shall be submitted in double-sided printouts. An exception is made to the Borehole Logs, the photographs of the borehole cores and the summary tables with the results of laboratory tests.
- The submissions of paragraph 11.5 shall be made as specified in this paragraph.

11.1.2 Review and resubmission periods

The review of the submissions specified in paragraphs 11.3.2, 11.3.3, 11.4 and 11.6 shall be completed by AM within fifteen (15) working days as of the date of the receipt of the submission. If further to AM’s review, the need for revision arises, the Contractor shall submit to AM the revision of the subject submission within fifteen (15) working days.

In case of multiple revisions, both the Contractor and AM shall have ten (10) working days for each submission or review respectively.

With regard to the submissions specified in paragraphs 11.2, 11.3.1 and 11.5, the content of these paragraphs shall apply.

11.2 Initial submissions after the signing of the Framework Agreement

11.2.1 Health and Safety Plan

The Contractor shall prepare the Health and Safety Plan (HSP) for the execution of investigation boreholes in line with the provisions of Presidential Decree 305/1996 and Ministerial Decisions no. ΔΙΠΑΔ/οικ/889 dated 27.11.2002 and ΔΙΠΑΔ/οικ/369 dated 15.10.2012 (circular 27).

The Contractor shall submit the HSP in hard copy and in electronic form to AM within a period of one (1) month as of the signing of the Framework Agreement. AM shall review it within ten (10) working days. In case of multiple revisions, both the Contractor and AM shall have ten (10) working days for each submission or review respectively. The commencement of the works at the borehole laboratories is not allowed if the HSP has not been approved beforehand.

Any supplementary submission containing modifications or additions to the HSP shall be made prior to the commencement of any works for which prior submission and approval the relevant modifications and approvals is a precondition. If at any given time, according to AM’s reasonable and documented judgment, AM deems that the HSP is insufficient or that its revision or modification is required in view of ensuring safe execution of the works or the protection of all workers or third parties, AM may instruct the Contractor to revise the HSP and the Contactor shall submit the revised HSP to AM for review within seven (7) working days.

The Contractor shall apply the principles and the procedures foreseen in the approved HSP and in any other approved modification or addition made to it and shall ensure that the implementation of the HSP is assigned to the appropriate personnel.

The minimum procedures to be developed in the HSP are the following:

- Incident reporting / investigation.
- Training of personnel in safety and fire safety issues.

- First aid.
- Written Occupational Risk Assessment.
- Management of inspections.

Additions to the aforementioned list shall be made further to AM's justified request.

11.2.2 Design Quality Plan

The Contractor shall prepare the Design Quality Plan for all investigations and studies, in compliance with ELOT ISO 10005 and Ministerial Decisions ΔΕΕΠΠ/οικ/502 dated 13.10.2000 and ΔΙΠΑΔ/οικ/501 dated 01.07.2003.

The Contractor shall submit the Design Quality Plan to AM in hard copy and in electronic form within a period of one (1) month at the latest as of the signing of the Framework Agreement. AM shall have ten (10) working days in order to review the Design Quality Plan. If revision of the Design Quality Plan is required, AM shall transmit to the Contractor the form "Design Quality Plan Completeness Review", foreseen by ΔΙΠΑΔ/οικ/501/01.07.2003, in order for the Contractor to complete and/or correct it and resubmit it. In case of multiple revisions, both the Contractor and AM shall have ten (10) working days for each submission or review respectively. The commencement of the works foreseen in the relevant design is not allowed if the Design Quality Plan has not been submitted beforehand, while in case of serious deficiencies in the submitted Design Quality Plan, AM may allow commencement of the design works only upon resubmission of the Design Quality Plan where such deficiencies will have been corrected.

In line with Ministerial Decision ΔΙΠΑΔ/οικ/501 dated 01.07.2003, indicative corrections to the Design Quality Plan are presented herebelow:

TABLE OF CONTENTS

1	General
1.1	Scope of the Design Quality Plan
1.2	Quality Policy
1.3	Structure of the Design Quality Plan
2	METHOD STATEMENT FOR THE PREPARATION OF THE DESIGN
2.1	Works and supporting means for the preparation of the design
2.2	Controls per section and in the entirety of the design
2.3	Verification of results
2.4	Design review
2.5	Controls and approvals by the Service
2.6	Management of modifications
2.7	Time schedule of the design works
2.8	Design progress
3	ORGANIZING THE PREPARATION OF THE DESIGN
3.1	Detailed description of the Organizational Chart for the preparation of the design
3.2	Organizational Chart
3.3	Subcontractors and external contractors of the designer
3.4	Equipment (software included)
4	MANAGEMENT OF DESIGN WORKS
4.1	Document management
4.2	Non Conformance – Corrective and preventive actions
5	OTHER ISSUES
5.1	Health and Safety
5.2	Protection of the environment
5.3	Training of the personnel of the Service
6	REFERENCES
	APPENDICES

The Geotechnical Investigation Organizational Chart (para. 5.1) shall be included in para. 3 of the Design Quality Plan.

In para. 4.1 of the Design Quality Plan, the following documents shall be submitted for approval:

- Pre-excavation pit report (§11.5.2).
- Trial pit report (§11.5.2).
- Borehole daily report (§11.5.1).
- Piezometer or pumping well installation report (§11.5.4).
- Laboratory tests programme table (§11.5.2).
- Pumping test report (§11.5.5).
- Borehole log (§11.6.2.1).
- HSCS data sheet (§18.11).
- The forms stated in the standardized references included in this document and are required for the execution of the works foreseen in the Framework Agreement – such as the forms specified in the standards concerning the execution of laboratory tests and on site testing

11.3 Submittals before the commencement of the investigations

11.3.1 Time schedule

The Contractor shall prepare a Time Schedule for each Individual Contract, in line with the specifications of article 2.1.6 of the *Conditions of Contract.*

11.3.2 Ground Investigation Report, Part A: Desk Study

The Contractor shall prepare a Desk Study using all information available prior to the geotechnical and geological investigation, so that at a subsequent stage he may proceed by himself with the planning and scheduling of the type, number and locations of the investigation works he will execute. The Desk Study shall be prepared in line with the requirements of this document and those of Eurocode 7 (chapter 2 and 6 of ELOT EN 1997-2) and shall be submitted within the deadlines foreseen in the approved time schedule.

The Desk Study is prepared based on the available data and the bibliography and after an *in-situ* inspection in the Study Area as well as in the wider area, in order to gather the required data.

The area extending at a distance up to 100 m from the Project's outline is considered to be the "Study Area" of the Desk Study. The "Wider Area" of the Desk Study is defined on per case basis and depending on the characteristics that are described and presented each time; in any case, the study area is included herein.

All maps of the Desk Study shall also depict the Project.

The submittal shall have the following chapters and structure, in general:

	TABLE OF CONTENTS
1	GENERAL
2	GEOMORPHOLOGICAL AND GEOLOGICAL CONDITIONS
3	URBAN CONDITIONS
4	ARCHAEOLOGICAL CONDITIONS
5	PREVIOUS GROUND INVESTIGATIONS AND AREAS OF WATER OCCURRENCE
6	CONCLUSIONS – GROUND INVESTIGATION PROPOSALS
7	BIBLIOGRAPHY
	APPENDICES

Chapter 1 shall contain:

- Contract details (design phase, title, decisions, Service, Contractor).
- Scope – Purpose of the Desk Study.
- Brief description of the Project.

Chapter 2 shall comprise the following (related to the Wider Area):

- Geomorphological description.
- Brief description of the geology (stratigraphy, tectonics).
- Reference to older and recent maps:
  - topographical
  - geological
  - hydrogeological
  - engineering geological
  - geotechnical
- Reference to old aerial photos.

Chapter 3 shall comprise the following (only for the Study Area):

- General description of the urban conditions (coverage and building density, free field, public buildings, infrastructure, main road arteries etc.).
- Land-use data (maps, photos, aerial photos etc.) with special reference to mines, quarries, backfills etc.
- History of previous land uses (maps, photos, aerial photos etc.) with special reference to previous industrial uses, uses such as refuelling stations etc., which could contaminate the ground and/or the groundwater.
- Recording in Tables and maps of the existing gas stations with their characteristics (location and distance from the Project, years of operation, number and location of pumps, dimensions and material of the fuel tanks, washing plants).
- Recording in Tables and maps of the main PUO networks.
- Especially as regards the rain / waste water drainage network, their characteristics shall be recorded on tables and maps: dimensions, depth, and type: uncovered, covered, backfilled, embedded, etc.
- Recording of possible are of contamination of ground and groundwater.

Chapter 4 comprises the following (only for the Study Area):

- Description of the conditions in terms of archaeology.
- Description and presentation on map of the archaeological sites.
- Reference to pertinent publications.
- Based on the evaluation of the above data, recording of possible locations were antiquities might be revealed.

Chapter 5 comprises a list of the earlier ground investigations and locations where water may be encountered, as per para. 92.3.4.

Chapter 6 shall evaluate all collected data and shall propose additional locations and type of geological and geotechnical investigations, in view of including them in the Ground Investigation Programme (para. 11.3.3).

The APPENDICES comprise the various maps, sketches, aerial photographs and other items described in the individual chapters.

11.3.3 Ground Investigation Programme

The Ground Investigation Programme shall consist of two parts, namely the Geotechnical Investigation Programme and the Geological Investigation Programme, and shall be submitted after the signing of each Individual Contract on the deadline foreseen in line with the requirements of the approved time schedule. In addition, if the submission of the Desk Study is foreseen in the scope of the Individual Contract, the Ground Investigation Programme shall be submitted after it.

11.3.3.1 Ground Investigation Programme, Part A: Geotechnical Investigation Programme

The Geotechnical Investigation Programme shall be prepared in line with the overall requirements of this document and those of Eurocode 7 (chapter 2 of ELOT EN 1997-2). The report to be submitted shall include as a minimum the following chapters and shall follow the structure presented herebelow:

	TABLE OF CONTENTS
1	GENERAL
1.1	Introduction - Scope
1.2	Normative references (§2.1, §8.3)
1.3	Relevant documents and drawings
2.	ORGANIZING THE BOREHOLE WORKSITES (§5.3, §5.4, §5.6)
3.	INVESTIGATION WORKS
3.1	Boreholes (§6.1, §6.13)
3.2	Piezometers (§6.1, §6.12, §12.7)
3.3	Sampling and sample handling methods (§6.4, §6.6.3, §6.6.4, §6.7.3, §6.8.3)
3.4	On site tests (§7.6)
3.5	Laboratory Tests (§8.3, §8.4)
3.6	Other investigations and tests
	APPENDICES
A	LAYOUT PLAN WITH THE LOCATIONS OF THE INVESTIGATIONS (§5.6.1)
B	GEOTECHNICAL INVESTIGATION ORGANIZATION CHART (§5.1)
C	TYPICAL PLAN VIEWS OF THE BOREHOLE WORKSITES (§5.3)
D	MECHANICAL EQUIPMENT LIST (§5.4)

Paragraph 1.1 shall include the following:

- Contract data (Project, contract, resolutions, Service, Contractor).
- Scope – Purpose of the geotechnical survey.

The remaining chapters shall be structured in line with their content. More precisely, paragraph 3.5 shall include, *inter alia*, a reference to the laboratories that the Contractor will use for the execution of all the tests of the Individual Contract stating clearly the type of the tests to be executed in each worksite, while data and certificates of any accredited laboratories which might not have been stated in the Contractor's Offer and which will be utilized in the execution of the specific tests, shall be also submitted (see also §8.1).

11.3.3.2 Ground Investigation Programme, Part B: Geological Investigation Programme

The Geological Investigation Programme shall be prepared in line with the content of paragraphs 9.2 and 9.3.

The report to be delivered shall include as a minimum the following chapters and shall be structured, in general, as follows:

	TABLE OF CONTENTS
1.	GENERAL
1.1	Introduction - Scope
1.2	Normative references
1.3	Relevant documents and drawings
2.	INVESTIGATION WORKS
2.1	Geological mapping
2.2	Recording of locations of earlier ground investigations and of water occurrence points

2.3	Groundwater level measurements
2.4	Tectonic diagrams – Potential slides
2.5	Geological mapping of slopes
2.6	Rock mass classification
2.7	Petrographical and mineral analyses
2.8	Engineering-geological map
2.9	Hydrolithological – Hydrogeological map
2.10	Other thematic maps
2.11	Geological works in sampling boreholes
2.12	Pumping tests
2.13	Rock Quality Designation (RQD)
2.14	Groundwater and ground chemical analyses
	APPENDICES
A	LAYOUT PLAN INDICATING THE LOCATIONS OF THE PROPOSED WORKS

Paragraph 1.1 shall include the following:

- Contract data (Project, contract, resolutions, Service, Contractor)
- Scope – Purpose of the geotechnical survey

Chapter 2.12 "Pumping tests" shall include the following (all references in brackets refer to ELOT EN ISO 22282-4):

- Preparatory Works
  - General (para. 5.1.1).
  - Test execution personnel, as per para. 5.1.
  - Required worksite installations with drawings, as per para. 5.3.
  - Required mechanical equipment, as per para. 5.4.
  - Determination of the discharge rate Q_d for the pumping test (para. 5.1.2).
- Disposal of discharge water (para. 5.2).
- Executing and equipping the test well (para. 5.3) with drawings.
- Executing and equipping the piezometers (para. 5.4) with drawings.
- Test execution (para. 5.5).
  - General – testing phases (para. 5.5.1).
  - Pre-pumping monitoring (para. 5.5.2).
  - Preliminary pumping phase (para. 5.5.3).
  - Pumping test (para. 5.5.4).
  - Post-pumping monitoring (para. 5.5.5).
- Uncertainty of measurements (para. 5.6).
- Interruptions in pumping (para. 5.7).
- Sealing of holes (para 6.13 herein) and worksite reinstatement (para. 6.14 herein).
- Recording of results – Forms: Pumping Test Report (para. A.2).
- Results evaluation method in order to determine hydraulic parameters k, T and S.
- Organization chart for the execution of pumping tests, in line with paragraph 5.1.

11.4 Material Submission Sheets

The Contractor submits for AM's approval the Material Submission Sheets (MSS) for all material, instruments etc. to be incorporated in the drilling works.

11.5 Submittals during the investigations

11.5.1 Borehole Daily Report

For each borehole (sampling or not, including the pumping wells), the Contractor shall compile a daily sheet which shall be submitted to AM at the beginning of the next working day. The details concerning the submission shall be defined in communication with AM.

The Borehole Daily Report contains the following:

1. Project name, Client, Contractor
2. Borehole code, type of borehole
3. S/N of Report, date, weather conditions
4. Borehole data:
   - sketch indicating the location of the borehole in line with para. 6.15 (it applies to the first Daily Works Sheet of each borehole)
   - Daily progress of the works
   - Total drilling time
   - Flushing medium
   - Casing data: diameter and beginning-end depths
   - Orientation of the drilling given as an angle to the horizontal level
5. Drilling rig data (type, capacity, power etc.)
6. Drilling and sampler's data (with references to the beginning-end of each 'drill run'):
   - Corebarrel - sampler type
   - Cutting tools type
   - Sampler's nominal diameter
   - Drilling time (drill run)
   - TCR, SCR, RQD and If (para. 13.2.11) for each rock core drilling step (on soil materials only ground sample recovery is measured; for the definition, see para. 3.3.15 of ELOT EN ISO 22475-1)
   - Casing and length diameter
   - Flushing medium returns' colour
   - Morning and evening water level
   - Water loss
7. Samples' data (with references to the beginning-end of each drill run):
   - S/N of sample
   - Type of sample
   - Diameter of sample
   - SPT
8. Vessel samples
9. Engineering geological description (as per para. 13.1):
   - soil and rock description
10. In situ water permeability measurements:
    - Depths of the tested section
    - Type of test
11. PID measurements
12. Pocket penetrometer measurements
13. Instrument installation
14. Backfilling and sealing works
15. Comments
16. Rig operator name
17. Borehole Geologist's Name and Signature

11.5.2 Pre-excavation Pit Report and Trial Pit Report

For each pre-excavation pit or trial pit, the Contractor shall prepare the corresponding report which, once completed, shall be submitted to AM at the beginning of the next working day. The details concerning the submission shall be defined in communication with AM.

The Report contains the following:

1. Project name, Client, Contractor.
2. Borehole code (for pre-excavation pit) or pit code (for trial pit).

3. Drilling date with reference to the depth at the end of each working day or shift.
4. Equipment which was used.
5. Data related to the quantity of water pumped from the pit.
6. Description of each formation, together with sketches of the formation encountered on the excavation sides.
7. Sampling locations and sample codes (in case of trial pit).
8. Sampling method (in case of trial pit).
9. The depths and results of all in-situ tests.
10. Details of time spent due to encountering of obstructions.
11. Details of PUO networks located.
12. Dimensions and final depth of the pit.
13. Remarks on the stability of the sides of the hole and notes of the support used.
14. Description of the backfill (backfill material, layers etc.) and the compaction.
15. Photographs of the pit's slopes and bottom.
16. Borehole Geologist's Name and Signature.

The Pre-excavation Pit or Trial Pit Reports are also submitted as part of the Geotechnical Investigation Factual Reports (see paragraph 11.6.2).

11.5.3 Macroscopic Description Borehole Report

It is compiled during the procedure of phase 2 of the engineering geological description, as described in para. 13.1. The details of the content and of the submission shall be defined in communication with AM.

11.5.4 Piezometer or Pumping Well Installation Report

It is compiled in accordance with para. 12.1.7 of the standard ELOT EN ISO 22475-1. The report shall include the following data of the piezometer or pumping well (a) sketch (section) with the construction data and the geological data (geological units) encountered during the drilling of the borehole (b) as well as the data obtained from the piezometer installation with air-lift (tables and water level recovery diagrams etc.).

The Piezometer or Pumping Well Installation Report shall be submitted to AM on the day that follows the installation of the piezometer with air-lift, by means to be agreed with AM. The reports for the installation of all piezometers / pumping wells utilized in the Investigation shall be also submitted as an appendix to the Geotechnical Investigation Factual Reports (para. 11.6.2) and in the Geological Design (para. 11.6.1) respectively.

11.5.5 Pumping Tests Report

It is compiled in line with the content of paragraph 7 of ELOT EN ISO 22282-4 and shall include the Field Report, as foreseen in para. 7.1 of the Standard, and the Test Report, foreseen in para. 7.2 of the Standard). The Report shall be submitted to AM upon completion of the pumping tests at a time to be agreed upon with AM. The Pumping Test Report shall be also submitted as an Appendix to the Geological Study (see para. 11.6.1 herein).

11.5.6 Summary Quantities Report

Each week or at times prescribed by AM, the Contractor compiles and submits to AM an electronic (excel format) summary report with all the quantities of drilling activities, in situ and laboratory tests. The contents and the form of submission of this report shall be agreed with AM.

11.5.7 Laboratory Test Programme Tables

These Tables shall be compiled and submitted according to para. 8.2 herein.

11.6 Submittals after the completion of investigations

11.6.1 Ground Investigation Report, Part B: Geological Design

The Geological Design shall be submitted upon the completion of the geological investigation works foreseen in the respective Individual Contract in agreement with the approved time schedule and shall include:

1. the Geological Design – Engineering Geological Report,
2. the Geological Design drawings and
3. the Geological Design – Pumping Tests Factual Report.

The Engineering Geological Report and the drawings of the Geological Design shall be submitted together. The Geological Design – Factual Report and Evaluation report of Pumping Tests Results can be submitted separately.

11.6.1.1 Geological Design – Engineering Geological Report

The Engineering Geological Report shall contain the following chapters with the following general structure:

	TABLE OF CONTENTS
1	GENERAL
1.1	Introduction - Scope
1.2	Normative references
1.3	Relevant documents and drawings
2	GEOLOGICAL CONDITIONS
2.1	Stratigraphy
2.2	Petrographical and mineral analyses
2.3	Tectonics
2.4	Seismicity
3	HYDROGEOLOGICAL CONDITIONS
3.1	Geomorphology
3.2	Hydrogeology
3.3	Groundwater level
4	ENGINEERING GEOLOGICAL PROPERTIES OF THE FORMATIONS
5	CHEMICAL ANALYSES
6	CONCLUSIONS – PROPOSALS
7	BIBLIOGRAPHY
	APPENDICES
	ELECTRONIC FILE AGS

Paragraph 1.1 shall include:

- Contract data (Project, Contract, Decisions, Service, Contractor)
- Scope and purpose of the Geological Design.
- Works – Work Group (description of the performed geological works, drawings accompanying the geological design, work group of the geological design).
- Project's location and details.

Paragraph 1.3 shall include:

- References to documents, drawings of the approved relative submissions (Desk Study, Ground Investigation Programme) as well as to the relative data which are co-evaluated in the specific design.

<u>2 Geological conditions</u>

Chapter 2 shall describe the geological conditions in the wider area of investigations, as follows:

Paragraph 2.1, stratigraphy:

- Description, age, geographical distribution and extent of the geological formations encountered in the broader Project's area, as well as their distinction in alpine and post-alpine.
- Brief description of the engineering geological formations forming the geological formations in the Project area, as well as of the petrographic types forming the engineering geological formations (detailed description in chapter 4).
- Representative tectonostratigraphic column in the investigation area, with the symbols of the geological formations.

Paragraph 2.2, petrography and mineral analyses:

- Results and commenting on the petrography and mineral analyses, according to para. 9.3.9.

Paragraph 2.3, tectonics:

- Brief description of the tectonic phases and neotectonic activity.
- Statistical processing of the orientation of bedding or foliation using appropriate stereographic projections (rose diagram, Schmidt net).
- Statistical processing of the orientation of the main tectonic structures using appropriate stereographic projections (rose diagram, Schmidt net).
- Description of the main tectonic structures, such as faults and shear zones in the wider area and in the investigation area: orientation, assessment of the shear zone and fault zone thickness, description of the fault rocks for faults and shear zones, classification as regards activity (accompanied by the proper photographic documentation, if feasible).
- Extracts from IGME's seismic-tectonic map, scale 1:500,000 or from published neotectonic maps, scale 1:100,000.

Paragraph 2.4, seismicity:

- Map of the wider area with the epicentres of major earthquakes, as well as a table with the respective epicentres (coordinates, time, magnitude, etc.).
- Reference to the impact of such earthquakes, e.g. damage caused to buildings and, in general, to structures, recorded ground raptures, occurred soil liquefaction, etc. .
- Classification of the ground conditions in terms of seismic hazard, as per Eurocode 8 (ELOT EN 1998-1).
- Analysis of the seismic-tectonic regime and assessment of the impact of the Project from the presence of any active faults.

3 Hydrogeological conditions

Chapter 3 shall describe the hydrogeological conditions in the wider area and in the investigation area, as follows:

Paragraph 3.1, geomorphology:

- Description of the geomorphological characteristics in the wider area and specifically in the Project's zone.
- Brief description of the hydrographic network in the wider area.
- Brief description of the hydrographic axes for drainage, which intersect the Project's alignment (along with suitable photographs, if feasible): recording of the study area hydrographic network's axes in tables and on maps and classification of them –if feasible– into natural, artificial uncovered, and artificial covered.

NOTE The term *natural* refers to a hydrographic axis that has suffered only minimum intervention (its flow has not been changed, it has not been encased, it is uncovered, etc.) while the term *artificial* refers to the hydrographic axis that has suffered interventions (its flow has been changed from its natural flow or/and it has been encased, etc.).

NOTE It is stressed that along its length a hydrographic axis can be classified to more than one category as per the above.

Paragraph 3.2, hydrogeology:

- Hydrolithology, characteristics of the groundwater tables: description and classification according to the permeability (primary or secondary) of the engineering geological formations. Tables and diagrams of the permeability coefficient (k) per engineering geological formation based on the *in-situ* test results. Description of the groundwater tables (type, thickness). Determination of hydraulic parameters (permeability *k*, transmissivity *T*, and storage coefficient *S*) of the groundwater tables based on the pumping tests, the *in-situ* permeability tests (test in boreholes, pumping tests) as well as based on the bibliography. Special reference shall be made to the presence of artesianism.
- Brief description of the locations where water, springs, areas susceptible to flooding, areas with ponding water (either seasonal or permanent), swamps, etc. are encountered (along with the relevant photographs, if feasible)

Paragraph 3.3, ground water level:

- Description of the ground water level variation:
  - Diagrams showing the fluctuation of the groundwater in time, per each piezometer and group of piezometers (depending on the case), which shall also present precipitation data (total precipitation) for the wider area.
  - Commenting on and evaluation of the groundwater level: reliability of the measurements (commenting and possible exclusion of non-assessable irregular measurements), sufficiency of the measurements (in relation to the hydrological cycle), annual variation of the level (dry and wet period), correlation to the precipitation data for that area (correlation between groundwater level variation and the precipitation in the wider area for the time period of the measurements, correlation between the precipitation data of the measurement period and the of the last e.g. 100 years), correlation to other measurements of the level in the wider area based on bibliography or other studies, correlation to the hydrolithological characteristics of the encountered water table (s).
- Description of the spatial distribution of the groundwater level:
  - Evaluation of the isopiezometric curves of the hydrogeological maps.
  - Observations regarding the discharge axes and correlation to the geomorphological characteristics in the area.
  - Observation regarding the hydraulic gradients in the various section of the study area, etc.
- Based on the above, an estimate of the upper and lower limits of the groundwater level, both for normal situations (high level, see para. 2.2.19 and low annual level), as well as for extreme situations (maximum level, see para, 2.2.2 and minimum level for 100-year period), according to the requirements of para. 3.6.3 of ELOT EN 1997-2. In case of insufficient data, conservative and documented assumptions shall be adopted as regards the limits of the level.

4 Engineering geological conditions

Chapter 4 describes the engineering geological formations as follows:

- Composition and structure:
  - Description of the units and petrographic types that form the formation.
  - Structure, heterogeneity, colour, texture of units / petrographic types.
- Rock mass characteristics:
  - Alteration and weathering.
  - Rock mass fracturing (RQD and SCR).

 - Rock mass classifications GSI (structure, discontinuities, range of values).
 - Degree of karstification.
- Assessment of the engineering geological behaviour during Project constructions, e.g.:
 - Stable excavation face / slope.
 - Occurrence of gravitational failures (wedges, blocks).
 - Occurrence of failures due to flow of geomaterials ("chimney" collapse, ravelling ground).
 - Occurrence of shear failures.
 - Occurrence of deformations (convergence).
 - Swelling ground.

NOTE For the assessment of the engineering geological behaviour during the Project's construction, we indicatively propose the paper: Marinos V. 2012, *Assessing Rock Mass Behaviour for Tunnelling*, Environmental & Engineering Geoscience, Vol. XVIII, No. 4, November 2012, pp. 327–341.

5 Chemical analyses

Chapter 5 presents and evaluates the results of the chemical analyses as follows:

- Cumulative tables with all results of chemical analyses and aggressivity tests for groundwater and ground (para. 8.4.3) as well as their evaluation in relation to their influence of structural elements in the ground.
- Presentation and evaluation of the chemical analyses results in relation to geochemical contamination (para. 2A.118.4.4).

6 Conclusions

Chapter 6 shall make a brief reference to the evaluation results obtained from each individual chapter. The main engineering geotechnical and hydrogeological characteristics of the engineering geological formations, the anticipated behaviour in engineering geological terms and the potential problems that may emerge during the Project's construction and operation are noted and delineated.

Moreover, based on the evaluation of all available geological investigations, additional geological and geotechnical investigations shall be proposed as deemed necessary, in order to supplement any insufficient available data or to respond to any questions posed by the results of the geological investigation, should the above evaluation so dictates.

Appendices

These shall include:

- A record of all registered locations of earlier ground investigations and location where water was encountered (para. 9.3.4).
- Tables with groundwater level measurements (para. 9.3.5).
- Measurements of the orientation of the discontinuities in the units (para. 9.3.6).
- Measurements of the orientation of the structural elements in the geological surveys of the slopes (para. 9.3.7).
- Tables with rock mass classification per engineering geological formation (para. 9.3.8).
- Reports on petrographical and mineral analyses (para. 9.3.9).
- Chemical analysis test reports (para. 9.3.16).
- Tables with RQD measurements per engineering geological formation (para. 9.3.15).

AGS electronic file

This AGS electronic file shall encompass all data to be submitted in AGS format in communication with AM.

11.6.1.2 Drawings of the Geological Design

The Geological Design shall contain at least the following drawings:

- Engineering Geological Map (para. 9.3.1)
- Hydrolithological – Hydrogeological Map (para. 9.3.11)
- Geological Surveying of Slopes (para. 9.3.7)

NOTE The Geological – Hydrogeological – Geotechnical Longitudinal Sections and Cross Sections shall accompany the Evaluation Report.

11.6.1.3 Geological Design – Factual Report and Evaluation Report of Pumping Tests Results

After the completion of the pumping test, the Contractor shall submit a Geological Design – Pumping Test Factual Report, as per the stipulations in ELOT EN ISO 22282-4.

The submittal shall contain the following chapters and shall follow the structure shown below (all references in parenthesis refer to ELOT EN ISO 22282-4):

TABLE OF CONTENTS

1 GENERAL
1.1 Introduction - Scope
1.2 Normative references
1.3 Relevant documents and drawings
2 TEST PREPARATION
2.1 General (para. 5.1.1)
2.2 Test execution personnel
2.3 Worksite installations
2.4 Mechanical equipment
2.5 Discharge rate Q_d of the pumping test (para. 5.1.2)
3 DISPOSAL OF DISCHARGE WATER (PARA. 5.2)
4 EXECUTING AND EQUIPPING THE TEST WELL (para. 5.3)
5 EXECUTING AND EQUIPPING THE PIEZOMETERS (para. 5.4)
6 PUMPING TEST
6.1 General – test phases (para. 5.5.1)
6.2 Pre-pumping monitoring (para. 5.5.2)
6.3 Preliminary pumping phase (para. 5.5.3)
6.4 Pumping test (para. 5.5.4)
6.5 Post-pumping monitoring (para. 5.5.5)
7 UNCERTAINTY OF MEASUREMENTS (para. 5.6)
8 INTERRUPTIONS IN PUMPING (if any, para. 5.7)
9 SEALING OF HOLES AND WORKSITE REINSTATEMENT
10 EVALUATION OF RESULTS – CALCULATION OF k, T AND S
11 BIBLIOGRAPHY
APPENDICES:
A LAYOUT PLAN WITH THE TEST WELL AND THE PIEZOMETERS
B PUMPING TESTS RECORDS
C EVALUATION SPREADSHEETS

ELECTRONIC AGS FILE

11.6.2 Ground Investigation Report, Part C: Geotechnical Investigation Factual Report

The Contractor may submit many Geotechnical Investigation Factual Reports in agreement with the approved time schedule.

Every Geotechnical Investigation Factual Report shall be drafted in line with the requirements of this document and Eurocode 7 (para. 3.4, ELOT EN 1997-1 and chapter 6, ELOT EN 1997-2). The title of the Report shall include the codes of the boreholes integrating the relevant borehole data. The Report shall include the following chapters–on a per case basis– and shall be structured as follows:

VOLUME 1: TECHNICAL REPORT

TABLE OF CONTENTS

1 GENERAL
1.1 Introduction – Scope
1.2 Normative references
1.3 Relevant documents and drawings
1.4 Description of the area
1.5 Information on in-situ works and worksite organization
2 PRE-EXCAVATION AND TRIAL PITS
3 BOREHOLES
3.1 Borehole data
3.1.1 Groundwater level measurement during drilling
3.2 Data from piezometers
3.2.1 Piezometer development works (air lift)
4 IN-SITU TESTS
4.1 Standard Penetration Tests (SPT)
4.2 Cone Penetration Tests (CPT)
4.3 Pressuremeter Tests
4.4 In-situ water permeability tests
4.5 Measurement of volatile organics
4.6 Other in situ tests
5 LABORATORY TESTS
5.1 Specifications for the execution and presentation of the soil / rock mechanics laboratory tests
5.2 Cumulative tables with results obtained from soil mechanics lab tests
5.3 Cumulative tables with results obtained from rock mechanics lab tests
6. DIFFERENTIATIONS BETWEEN GI EXECUTED WORKS AND THE RESPECTIVE PAST GI WORKS
7 BIBLIOGRAPHY

APPENDICES

A LAYOUT PLAN OF THE GROUND INVESTIGATION LOCATIONS (paragraph 6.15)
B PRE-EXCAVATION & TRIAL PIT FORMS (PARA. 11.5.2), SKETCHES INDICATING THE LOCATIONS OF THE BOREHOLES (para. 6.15)
C BOREHOLE LOGS (para. 11.6.2.1)
D PHOTOGRAPHS OF BOREHOLE CORES (para. 10.3)
E PROPOSED AND EXECUTED LABORATORY TEST PROGRAMME TABLES (para. 8.2)
F PIEZOMETER INSTALLATION REPORTS (para. 11.5.4)

VOLUME 2: IN-SITU TEST REPORTS (para. 7.7)

VOLUME 3: LAB TEST REPORTS (para. 8.5)

VOLUME 4: LAB & IN-SITU TEST REPORTS (unofficial records during test execution – only in a digital format (pdf file))

AGS ELECTRONIC FILE (Appendix E)

Paragraph 1.1 shall include:

- Contract data (Project, Contract, resolutions, Service, Contractor)
- Scope and purpose.
- Project's location and details.

Chapter 3 presents in summary the data for all boreholes (sampling with piezometer, sampling without piezometer, non-sampling with piezometer, piezometric boreholes, investigation water-jet drilling): codes, drilling depths, coordinates of the Thessaloniki Metro Development Plan, drilling works commencement and completion dates, installed piezometers data (installation depth of blind, perforated pipes and gravel filter), construction data investigation water-jet drillings. The remaining chapters shall be developed in line with their content.

If the Geotechnical Investigation includes laboratory or in-situ tests and, in general, works not falling in the content presented above, the Contractor shall complete them accordingly, in agreement with AM.

11.6.2.1 Borehole Logs

The Borehole Logs shall be standardized documents. They concern the sampling boreholes and shall be submitted to AM for approval as part of the respective GI Factual Reports (§11.6.2).

The “Borehole Log” form shall be compiled as shown below (see also Appendix D), taking also into account the requirements in para. 1.5 (d) of E 104-85.

The Borehole Log includes the following data:

1. Project name, Client, Contractor's name
2. Borehole No. coordinates of borehole, angle from the horizontal
3. Groundwater data (with references to depths): morning water level, night water level)
4. Drilling and sampling data:
   - Type and nominal diameter of corebarrel-sampler
   - Drilling time (min)
   - Diameter of casing (if used)
   - Flushing medium returns (%)
   - TCR (%) or TC (%)
   - SCR (%)
   - RQD (%)
5. Engineering geological description (phase 4) with references to depths (as per Appendix B):
   - units’ symbols (following ISO 710-1 to ISO 710-7 standards)
   - description of engineering geological units
6. Rock mass classifications, GSI (structure, discontinuities’ condition, value range, as per para. 14.2), with reference to depths
7. Rock strength (bar chart, as per 13.2.2)
8. Rock mass weathering (bar chart, as per 13.2.12)
9. Description of discontinuities (type and characteristics, as per para. 13.2.10)
10. Strength for cohesive soils (bar chart, as per 13.3.6)
11. Consistency of fine-grained soils and density of coarse-grained soils (bar charts, as per 13.3.2):
12. In-situ tests, with references to depths:
    - SPT (record the depth of test commencement, the blow count per step, N_{SPT}, penetration)
    - c_U with pocket penetrometer
    - Permeability tests (test type, depth of the tested section, value)
13. Sample info (sample depths, code)
14. Laboratory tests:
    - HSCS soil group symbol, according to Appendix G
    - Physical properties
    - Mechanical properties
    - C.E.R.CHAR Abrasivity Test (CAI)

- Petrographical analyses (only depth of the samples)
- XRD tests (only depth of the samples)

15. Scale: the scale for the depth shall be 1:50.

11.6.3 Ground Investigation Report, Part D: Evaluation Report of the Geotechnical Investigation Results – Geological, Hydrogeological, Geotechnical Profile and Cross-sections

11.6.3.1 General

The report shall be submitted upon approval of the corresponding Geotechnical Investigation Factual Report(s) and in compliance with the requirements of the approved time schedule.

The Evaluation Report of the Geotechnical Investigation Results shall be developed in line with the requirements of this document and Eurocode 7 (para. 3.4 ELOT EN 1997-1 and chapter 6 ELOT EN 1997-2). In the report, the data of the present geotechnical investigation shall be co-evaluated with the existing data and with all the available data that the Contractor will collect.

Any evaluation related-issues shall be addressed in meetings to be held between the Contractor and AM prior to the completion of the report.

11.6.3.2 Determination of the Engineering Geological Formations

In the framework of evaluating and interpreting the GI data, the Contractor shall group the engineering geological units (as they will result from the descriptions of the cores from borehole and trial pits) into engineering geological formations. The classification and eventually the grouping of the engineering geological units into engineering geological formations shall be based on the evaluation of all available data from the geological and geotechnical investigations. The engineering geological formations that will be finalized in the framework of the evaluation, shall be accompanied by the ranges of the geotechnical parameters and shall be presented in the Geological – Hydrogeological – Geotechnical Longitudinal Section.

11.6.3.3 Stages of the evaluation

This paragraph describes the stages of evaluation of the available results from the GI of this Contract and any previous investigations.

1st stage

Finalization of the engineering geological formations after the grouping of the engineering geological units. The engineering geological formations are defined at the time of preparation of the Geological – Hydrogeological – Geotechnical Longitudinal Section.

2nd stage

Statistical processing of the rock mechanics test results on the physical and mechanical properties per pertographic type, separately for each engineering geological formation and as a whole, irrespective of the engineering geological formation this type belongs to. The output of this processing shall be test result tables, diagrams, etc.

3rd stage:

Evaluation of all physical and mechanical properties results (obtained from rock mechanics, soil mechanics and *in-situ* tests) per engineering geological formation. The output of the evaluation shall be the ranges of the parameters.

The above stages are not necessarily successive. For example, the engineering geological formations are defined after the 3rd stage, since in many occasions the completion of the statistical processing of the data may necessitate changes to the Geological – Hydrogeological – Geotechnical Longitudinal Section and thus to the structure and distribution of the engineering geological formations.

In case of rock masses, the rock mechanics lab test results shall be correlated with pertographic types, while the soil mechanics lab and *in-situ* test results shall be correlated with engineering geological formations. In the case of soil units, the results of the lab and *in-situ* tests shall be always correlated with engineering geological formations. Therefore, all data shall be initially (and on per case basis) correlated with petrographic types (2nd stage) and subsequently with engineering geological formations (3rd stage), on the basis of the required evaluation.

The output of the statistical processing (tables, diagrams) shall be described per test type or parameters examined in para. 11.6.3.4.

11.6.3.4 Structure and contents of the Evaluation Report of Geotechnical Investigation Results

The Evaluation Report of Geotechnical Investigation Results shall comprise the following chapters and shall have the following structure:

TABLE OF CONTENTS

Chapter 1 shall contain Contract details (design phase, title, decisions, Service, Contractor), the scope and purpose of the Geotechnical Investigation. It shall also contain the codes and standards used, references to documents, documents, drawings of the approved prerequisites and of the relevant submittals (Desk Study, GI Programme, GI Factual Reports) (Geological – Hydrogeological – Geotechnical

Longitudinal Section and Cross Sections) as well as all other data which are co-evaluated in the framework of the specific Evaluation Report.

Chapter 2 describes the Project's location and details.

In chapter 3, the principles of interpretation methodology will be described.

Chapter 4 highlights and comments upon any remarks related to the completeness, quality and reliability of the data (e.g. deficient, irrelevant, insufficient or inaccurate) that resulted from the Contractor's GI as well as from pre-existing investigations. Sampling procedures and the procedures for sample transportation and storage shall be taken into account in the interpretation of the test results. Any out-of-scale results shall be carefully examined in order to determine whether they are not representative or represent an actual situation that has to be taken into account in the preparation of the Project's design. Upon completion of the above commenting, at the end of the chapter a table shall be drafted listing the test results that are excluded from the evaluation. For each excluded test result, the reason for its exclusion shall be provided, on the basis of the above comments. Chapter 4 shall also provide a comparison between the results of the GI carried out by the Contractor and the results of earlier geotechnical investigations, as well as any other data the Contractor may have gathered in relation to the geological, hydrogeological and engineering geological conditions.

Chapter 5 briefly describes the geological conditions in the Project Area, with references to the respective chapter of the Geological Design.

Chapter 6 records the engineering geological conditions. More precisely, recorded are the characteristics of the engineering geological units described in the sampling boreholes, the engineering geological formations into which units are grouped and the rocky engineering geological units of the lithological types participating in them.

Chapter 7 briefly describes the Hydrogeological conditions in the Project Area, with references to the respective chapter of the Geological Design. This chapter also describes at least the following:

- Determination of hydraulic parameters per engineering geological unit.
- Determination and description of the groundwater table(s) (from the Geological Design).
- Higher and lower ground water levels in normal (e.g. highest and lowest measured level) and extreme conditions (maximum and minimum levels in 100-year period) (from the Geological Design).
- Assessment of the groundwater table(s) behaviour during the project's construction / operation.
- Brief description of groundwater impact on the project's construction and operation.

This chapter shall deal with the following as a minimum:

- Permeability tables for each engineering geological formation.
- Water permeability distribution bar charts for each engineering geological formation.

Chapter 8 is where all data (physical, mechanical and engineering geological properties) are analyzed per engineering geological formation.

In this chapter the petrographic types and the engineering geological formations shall be classified as ground, rock mass with infrequent and rare discontinuities or as rock masses. For each petrographic type and engineering geological formation, cumulative tables shall be given presenting their physical and mechanical properties, as well as the respective diagrams.

These cumulative tables shall include the results of all tests and all required data per test; these tables shall present at least the following:

- Multitude of tests or length of the evaluated core (e.g. RQD, GSI) respectively.
- Range of values (min - max).
- Average value.
- Standard deviation.

The diagrams to be prepared for each petrographic type and each engineering geological formation shall be the following as a minimum:

- GSI distribution diagrams or histograms
- RQD distribution diagrams or histograms.
- Diagrams or histograms with the distribution of all physical properties.
- Particle size distribution diagrams (particle size distribution curves, see Figure 18.2).
- Plasticity diagrams (see Figure 18.3).
- Distribution diagrams or histograms of the Standard Penetration Test (SPT) results.
- Distribution diagrams of the Standard Penetration Test (SPT) results in relation to the depth.
- Diagrams or histograms with the distribution of mechanical properties.
- Diagrams of the "elasticity modulus – strength", based on the uniaxial tests results.
- Diagrams with the results of triaxial tests or shear tests on soil specimens in the form of "cohesion – friction angle" (total, undrained or active parameters).
- Diagrams with the results of shear tests on rock discontinuities in the form of "cohesion – friction angle".

Paragraph 8.6 shall evaluate all data per engineering geological formation as required, in order to extract the ranges for the following parameters (per case):

- For rock engineering geological formation: unit weight (γ), permeability coefficient (k), geological strength index (GSI), intact rock strength (σ_{Ci}), m_i constant, intact rock modulus of elasticity (E_i) and/or MR ratio.
- For soil engineering geological formation: wet unit weight (γ_w), dry unit weight (γ_d), plasticity index (I_P), consistency index (I_C), activity index (I_A) permeability coefficient (k), blows per standard penetration test (N_{SPT}), unconfined compression strength (q_u), undrained shear strength (c_u), total strength parameters (c and φ), active strength parameters (c' and φ'), pressuremeter moduli, over-consolidation ratio (OCR), compression modulus (E_s), compression modulus (C_c), swelling behaviour.

Paragraph 8.7 presents the risk assessment for liquefaction phenomena, taking into account the results of all available tests (particicle size analysis, SPT, CPT, etc.). The assessment method statement, selected on the basis of the relevant results, shall be clearly described and shall be an internationally recognized and widely accepted reliable method for calculating the safety coefficient against liquefaction for the Project Area.

Based on the above, the possibility of the occurrence of liquefaction phenomena shall be commented and assessed, while any problems likely to result from the Project construction and operation shall be noted. If necessary, any additional investigations deemed advisable to be executed at a subsequent design stage (see also chapter 10) shall be proposed.

Chapter 9 divides the Project into sections, according to the engineering geological and geotechnical conditions, so that each individual section corresponds to almost homogeneous geotechnical and engineering geological conditions.

This chapter shall incorporate properly scaled profiles, which shall present the necessary data according to the engineering geological conditions along the Project. As an example, this information can be the following:

- Permeability

- Presence of d (karstic voids, ducts, wells etc.)
- GSI
- RQD
- σ_{Ci} and q_u
- N_{SPT}
- Liquid limit (w_L)
- Consistency Index (I_C)
- Presence of boulders and large boulders.

Chapter 10 shall make a brief reference to the evaluation results. In addition, based on the evaluation of all available geological and geotechnical data, geotechnical surveys, proposals shall be made for any additional geological and geotechnical investigations deemed necessary; in order to supplement the survey data or to clarify any unclear points rose from the results of the GI, should it be dictated by the above evaluation.

11.6.3.5 Geological, Hydrogeological, Geotechnical Longitudinal Section and Geological – Hydrogeological – Geotechnical Cross Sections

The Geological, Hydrogeological, Geotechnical Longitudinal Section and the Geological, Hydrogeological, Geotechnical Cross Sections shall be submitted along with the Evaluation Report of Geotechnical Investigation Results.

The aforementioned longitudinal sections and cross sections shall be designed on the basis of the following:

a) The longitudinal profile shall be designed on the basis of the Project's longitudinal profile (in general, along the right truck as the KP increases) tunnel axis.

b) The scale of the longitudinal section of the entire Project shall be 1:2,000 horizontally and 1:400 vertically.

c) The scales of the cross sections shall be 1:500 horizontally and vertically or other, as agreed with AM.

d) Geological – Hydrogeological– Geotechnical Longitudinal Sections shall be divided into three parts (A, B and C), as follows:

e) Part A shall depict the General Layout Plan of the Project with the topographical base map on the same scale (1:2,000) as the horizontal scale of the longitudinal section, which shall include, as a minimum, the following items:
   - The boreholes of the Contract and other available investigations with different symbols or colours, depending on the phase of the research (boreholes from this Contract, boreholes from previous investigations) and depending on the type (sampling with piezometer, sampling without piezometer, non-sampling with piezometer, pressuremeter, CPT, pumping well, etc.).
   - The trial pit of this contract and other earlier investigations.
   - Main sewage pipes and any other critical public utility networks.
   - The main hydrographic axes in different colour, depending on their classification (para. 11.6.1.1).

f) Part B shall depict the Geological, Hydrogeological, Geotechnical Longitudinal Section, which shall contain at least the following:
   - Engineering geological formations, which are presented using suitable colours / symbols to be agreed upon with AM and their contact, distinguished –on a per case basis– into normal transition, unconformity, shear zone, fault
   - High and maximum groundwater level, as assessed in the Geological Design.
   - A cross section of the project axis with the Project's structures (tunnel cross section, station envelope, envelopes or projections of shafts with the respective KP on the top part of the profile).

- Project axis / ground surface interface.
- Project axis with buildings) approximately).
- Locations of the hydrographic axes and their respective KP.
- Main sewage pipes and any other critical PUO networks, with the respective KP on the top part of the profile.
- Scale of the elevation at the two ends of the drawing.
- Borehole projection –column thickness 5 mm– with the following data:
  i. Code name, absolute head elevation and depth of borehole.
  ii. Items within the borehole column: engineering geological units using the appropriate symbols in accordance with ISO 710.
  iii. Items on either side of the borehole column: on the left: high groundwater level, *k* in the middle of the tested length, and on the left, for soil units: symbol of HSCS soil group at the classification sampling position, q_u at the sampling position, N_{SPT} at the testing point, for rock units: σ_{ci} at the sampling position, GSI (GSI range, rock mass structure and condition of discontinuities) in the middle of the evaluated core length.
- The trial pits.

g) Part C shall present the following longitudinal profile data:
- Project axis KPs.
- Ground elevation.
- Top of Rail (TOR) elevation.
- Thickness of overburden (for the tunnels).
- KP of borehole projections to the Project axis.
- Presence of buildings over the tunnel's cross section.
- Segregation of the Project into sections, as per chapter 9 of the evaluation report.

h) There shall be a distinction among the individual sections, in line with Chapter 9 of the Report and for each section of the Project a Table shall be presented with the ranges of the geotechnical parameters for each engineering geological unit.

The drawing shall incorporate the following legends: (a) engineering geological formations, (b) engineering geological units, (c) sampling boreholes, (d) geological contacts and (e) other data.

11.6.4 Ground Investigation Report, Part E: Groundwater Level Measurements

The Contractor shall submit in printed and electronic form all the level measurements that he carried out throughout the duration of the present Contract (see § 9.3.5). A clear distinction between the measurements included in the Geological design and future measurements shall be made.

12 APPENDIX A: Installation and maintenance of piezometers

12.1 General

Installation and maintenance of piezometers shall be in accordance with the provisions of chapter 9 of standard ELOT EN ISO 22475-1 as well as with the following.

The following types of piezometers will be installed in boreholes:

- open systems (open standpipe or open pipe with inner hose)
- closed systems (hydraulic, pneumatic and electrical)

The choice of the type of piezometer which shall be installed depends on the permeability of the formation, the rate of change of pore water pressure and the required accuracy and duration of measurements.

Open systems are preferable for measurement of water level in soils or rocks of medium to high permeability and, generally, they should not be used for measurement of water level in soils and rocks with very low permeability or for monitoring rapid fluctuations of pore water pressure in low permeability soils and rocks.

Closed systems may be used for measurement of pore water pressure and as such the distribution of the hydraulic potential in all types of soil. More specifically, closed systems are required for the determination of pore water pressure in soils or rocks with very low permeability, for monitoring rapid fluctuations of pore water pressure and for cases of artesianism.

Installation of piezometers must not affect on a permanent basis the quality and flow of ground water, in accordance with the provisions of para. 9.3.1.1.3 of the standard ELOT EN ISO 22475-1.

Piezometer caps shall be protected and will be constructed in accordance with the provisions of para. 12.7. Open system piezometers' caps will not protrude from the ground surface or sidewalk or pavement.

The Contractor, prior to the installation of the piezometer, will submit an Instrument Installation Announcement Report and after installation the Contractor will submit a Piezometer Installation Report.

12.2 Materials

- Pipes and filter pipes of the open system piezometers shall be heavy duty PVC-U according to the standard ELOT EN 1329-1 with a 50mm outer diameter. Filter pipes must bear sufficient slots to allow free water flow yet should not be in danger of breaking.
- Open pipe with inner hose piezometers shall comprise at their lower end a porous ceramic or plastic element with an external diameter greater than 50 mm and length no less than 200 mm. This element will have appropriate characteristics (permeability, length, pore diameter) depending on the formation characteristics in which it is installed, in the order of 50 to 60cm. The permeability of the element will be slightly greater (up to one order of magnitude) than the one of the formation at the location of the installation.
- Electrical piezometers consist of a porous ceramic element or other material approved by AM with an external diameter greater than 30mm. This element will have appropriate characteristics (permeability, length, pore diameter) depending on the formation characteristics in which it is installed. The permeability of the element will be slightly greater (up to one order of magnitude) than the one of the formation at the location of the installation. The electrical leads are protected by a PVC-U outer cover.

- The filter which is placed in the perimeter of the casings is clean filter sand within grading limits of 0.2 and 1.2 mm, or clean rounded gravel of 2 mm to 5 mm, preferably of river origin and silicate composition. It is supplied on site in sealed bags. The Contractor will submit to AM for approval the grading of the filter that he intends to use.
- The bentonite which will be used for sealing shall be in the form of lumps or pellets and the bentonite which will be used for the preparation of grout shall be clayey.
- The sealing grout shall consist of sand and clayey bentonite in the proportion of 2:1 by weight. The quantity of the added mixing water shall allow the formation of a pumpable mix.
- The concrete used in the capping arrangements shall be C10/15.

At the worksite, there will be a sufficient quantity of all materials required for the installation of piezometers.

The quantity of the materials to be used for the execution of works will be accurately measured prior to the installation and a record of the used quantities will be kept.

12.3 Installation of open standpipe piezometers

1. Before the installation of piezometer, the borehole depth is checked. There must be no excavation spoil more than 20 cm thick. In case there are excavation spoil more than 20 cm thick the borehole will be cleaned.
2. The pipes are glued together with fast setting special glue for PVC and adhesive tape for better protection of the joints, in order to ensure they remain watertight and fixed before and after their installation at the borehole.
3. The perforated or slotted section of the pipes must be protected by plastic mesh in two layers. Placement of the mesh must be done carefully with overlap of 2-3 cm. The second layer follows with reverse direction.
4. Initially, bentonite lumps are placed at the bottom of the borehole in order to form a seal of at least 50 cm thickness.
5. First stage of filter installation follows: upon the bentonite seal and before the installation of the pipes, filter of 30 cm thickness is installed.
6. If the depth of the borehole is 1.5 m greater than the installation depth then, at the bottom of the borehole, grout is injected with the use of tremie pipe in a way that the upper edge of the grout is at least 0.8 m below the scheduled base of the filter. Following, stages 4 and 5 are implemented.
7. After first stage of filter installation the pipes are installed with the use of spacers in order to ensure their installation at the centre of the borehole.
8. Second stage of filter installation: the rest of the filter is placed continuously and in small quantities so as to avoid caving and achieve a homogenous filling of the gap between pipes and ground. The filter shall be installed up to 30 cm above the perforated pipe.
9. Then, another layer of bentonite pellets or lumps is placed in order to ensure that the length of the seal is not less than 50 cm.
10. Then, grout is placed up to the borehole cap, using a tremie pipe. The next day, the grout is filled if required.
11. The capping arrangements (paragraph 12.7) are executed the soonest possible following the completion of the piezometer installation. Until the caps are complete and secure, the Contractor is responsible for the safety and security of the installation.

12.4 Installation of open pipe with inner hose piezometers

1. Stage 1 of para.12.3.
2. The pipes are glued together with fast setting special glue for PVC and adhesive tape for better protection of the joints, in order to ensure they remain watertight

and fixed before and after their installation at the borehole. The porous element is fitted at the lower end of the pipes.

3. Stage 4 of para. 12.3.
4. Stage 5 of para. 12.3.
5. Stage 5 of para. 12.3.
6. The pipes and the porous element are installed.
7. Second stage of filter installation: the rest of the filter is placed in such a manner to secure a 30 cm coverage above the porous element.
8. Stage 9 of para. 12.3.
9. Stage 10 of para. 12.3.
10. Stage 11 of para. 12.3.

12.5 Installation of closed electrical piezometers

1. Stage 1 of para. 12.3.
2. Stage 4 of para. 12.3.
3. Stage 5 of para. 12.3.
4. Stage 6 of para. 12.3.
5. The electrical instrument is installed. The cables shall be protected by tubing, flexible or not, which terminate at the borehole cap.
6. Second stage of filter installation: the rest of the filter is placed in such a manner to secure a 30 cm coverage above the porous element.
7. Stage 9 of para. 12.3.
8. Stage 10 of para. 12.3.
9. Stage 11 of para. 12.3.
10. Where required, the electric cables are taken from the borehole to a remote terminal unit. The details are agreed with AM before each installation. Where the cable tubing is laid in trenches, the depth is not less than 30 cm from the surface and surrounded with sand. The pipes are coded with marker tape every 2 m to allow their identification and such identification is permanently marked on the terminal unit.

12.6 Verification of installation of piezometers

12.6.1 General

Upon completion of the installation the Contractor will prove that the piezometer operates properly. The verification of installation of the various piezometer types is executed in accordance with the provisions of para. 9.3.2 of the standard ELOT EN ISO 22475-1. For open standpipe piezometers, the provisions of para. 12.6.2 herein apply.

In case the piezometer is out of order, the Contractor will repeat the whole procedure related to the borehole execution and piezometer installation at a nearby location at his own expense.

12.6.2 Open standpipe piezometers' development procedure

The verification of installation of open standpipe piezometers is executed using the piezometer development procedure by the air-lift method as follows:

1. Measurement of ground water level before any action.
2. Installation of the nozzle connected to the air/water pipe. The nozzle shall be made of metal, at least 2 m long and placed at the deepest point of the borehole. The nozzle outlet shall be facing upward, so as to facilitate the air/water movement without damaging the lower part of the piezometer.
3. Cleaning with fresh water of low pressure and normal flow and mixing up with slight movement of the pipe up and down.
4. Cleaning with water stops when water coming out of the borehole is relatively clear

and there is no coarse-grained material.

5. Then, the procedure of pressing air into the piezometer. The air pressure increases progressively, until counterbalancing the water column and causing water to come out of the pipe with as normal flow as possible. Extraction of water with high pressure must be avoided, in view of preventing water from being trapped into the piezometer filter or around it.
6. Low pressure air compressor shall be used (up to 100 psi) and sufficient supply (> 200 ft^3/min).
7. The duration of the air-lift shall be as required so that the water coming out of the piezometer is clear.
8. In case of non-clear water, the cleaning with fresh water is repeated.
9. Then, measurements of restoration of the water level are performed and recorded, in order to determine the normal operation of the piezometer.

12.7 Construction of piezometer head

As soon as installation works are completed, protective measures shall be implemented as per para. 9.1.2.5 of ELOT EN ISO 22475-1 (see also appendix E of standard ELOT EN ISO 22475-1).

The termination of the piezometer pipe shall be properly capped within a suitably configured manhole, covered with heavy duty lid. The top surface of the lid shall not protrude from the reinstated area. The design of the piezometer protection measures, the details and the required materials shall be proposed by the Contractor in the Ground Investigation Programme.

When artesian conditions are encountered with water flowing on the surface, the Contractor shall necessarily install closed type piezometer and shall seal the hole with grout.

12.8 Piezometer maintenance

The Contractor shall ensure the proper operation of the piezometers throughout the Projects' duration by executing periodical maintenance inspections, as well as whenever there is evidence that piezometers are 'blocked'.

Maintenance inspections of the piezometers are carried out in accordance with the provisions of para. 9.4 of ELOT EN ISO 22475-1.

13 APPENDIX B: Engineering geological description of borehole cores

13.1 Principles and procedure of the engineering geological description

The engineering geological description refers to engineering geological units (units in short). The procedure of the engineering geological description refers to two distinct methodologies: the description of rocks and the description of soils, in accordance with the references of the following paragraphs.

An engineering geological description is made for all sampling cores and in all trial pits, as stipulated herein and it is gradually realised in the following four distinct and successive phases:

Phase 1

Description of the cores by the Borehole Geologist during the drilling: rudimentary macroscopic description of soil and rock units (name of unit) and determination of TCR, SCR, RQD and If (for rock core drilling), or TC (for soil core drilling). These data are recorded in the Daily Borehole Sheet.

Phase 2

Detailed macroscopic description of soil and rock carried out by the Engineering Geological Description Geologist during the inspection of the cores of a borehole or a group of boreholes: an analytical macroscopic description of all necessary soil and rock characteristics, rock mass classification (GSI), the determination of the unit boundaries as well as the primary assignment of the geological formation are carried out at this phase. Data are recorded in the Macroscopic Description Borehole Report. At this phase, the borehole cores are photographed per core box. After the description of borehole cores, sample selection for laboratory testing takes place under the supervision of the Head of Laboratory, as well as the description of the pertographic type for each sample. The works of this phase take place at an appropriately sheltered area, to allow all core boxes of the boreholes to be described to be able to be opened simultaneously. The Contractor will provide all necessary materials for the works of this phase (geological hammer, water supply for the sprinkling of the borehole cores prior to description, hydrochloric acid, magnifying glass, soil cutting tools, colour scale, architect's scale, tape measure, sample cling film, sample collection containers, empty core boxes for the transportation of the samples to the laboratory etc.).

Phase 3

Macroscopic description of samples (or specimens) during execution of the laboratory tests. The Head of Laboratory shall examine the sample (or specimen) in relation to the description of the lithological type of the phase 2 sample (or phase 1 for samples from trial pits). Whenever there is difference between the description of the lithological type of the sample and the description in phase 2 (or in phase 1), the new description is recorded. The lithology type of the sample is recorded in the respective laboratory test sheet, which shall be attached to the GI Factual Report (para. 11.6.2).

Phase 4

Compilation of the Borehole Log by the Engineering Geological Description Geologist, where the description of each formation is finalised after the co-evaluation of all available data (macroscopic description, laboratory and in situ test results, correlation of formations in adjacent boreholes etc.).

Note For the description of phase 2, the Contractor shall timely inform AM about the time and place of the opening of the core boxes in order for a representative to be present. After the end of phase 2, copies of the Macroscopic Description Borehole Sheets shall be handed to AM.

NOTE At phase 2, the group of boreholes which are to be described shall, as far as possible, consist of adjacent boreholes to allow for a better determination and correlation of the formations. The Engineering Geological Description Geologist shall bear the Daily Borehole Sheets of the group of boreholes in order to be used for the engineering geological description.

The engineering geological description of the units in the trial pits shall be carried out by the Engineering Geological Description Geologist and shall be recorded in the Trial Pit Report. The selection of samples for the trial pit shall be carried out under the direction of the Lab Official.

NOTE For the description these sample, the Contractor shall timely inform AM about the time and place of the opening of the core boxes in order for a representative to be present.

13.2 Engineering geological description of rock units

13.2.1 General

The description of the rock unit shall correspond to that of the rock (lithological or petrographic type) it is composed of. Whenever the unit is made of more than one rock types, the description of the unit shall result from the synthesis of the description of the described rock types. The methodology of the engineering geological description of rocks shall follow the provisions of the standard ELOT EN ISO 14689.

All rock characteristics which are examined and recorded in the succession given below:

1. Unconfined compressive strength of intact rock.
2. Rock structure.
3. Rock colour.
4. Rock texture.
5. Rock grain / mineral size.
6. Rock weathering and alteration.
7. Unit name (in uppercase).
8. Geological formation (in parentheses, in uppercase).
9. Rock mass discontinuities.
10. Core recovery and core fracture state of rock mass.
11. Rock mass weathering.
12. Additional characteristics.

NOTE From the above characteristics, elements 1 to 8 and 12 are reported in the unit description field of the Macroscopic Description Report and the Borehole Sheet. Elements 9 to 11 are recorded in the respective fields of the Borehole Log and may be reported in the unit description field, wholly or partially, only when deemed necessary (e.g. "discontinuities with filled with calcite", "total core recovery 20 %" etc.).

NOTE Description of elements 1 to 8 (rock characteristics) is reported in one sentence. A sentence for elements 9 to 11 (rock mass characteristics) and 12 (additional data and information) follows, whenever deemed necessary.

NOTE In cases of alternations of rocks with different geotechnical properties, the description shall be a synthesis of the descriptions of the two types when layers are distinct, regardless whether the form a unified unit. Whenever the alternations are of such a scale that does not allow the distinct description of the individual rock types, the description will be unified.

EXAMPLEAlterations of medium strong, with thick foliage, green-grey, faded META-SILTSTONE (ATHENS SCHIST, LOWER FORMATION). The unit appears slightly folded.

Guidelines are given below for the description of the individual characteristics which are examined.

13.2.2 Unconfined compressive strength of intact rock

The unconfined compressive strength (UCS) of intact rock is reported in accordance with the provisions of para. 5.3 of the ELOT EN ISO 14689 standard. During phase 2, UCS is identified macroscopically based on Table B.1. If necessary, UCS is corrected at phase 4 based on the results of the laboratory tests.

Table 13.1: Field identification of the unconfined compressive strength

Term	Identification by hand test	Unconfined compressive strength (MPa)
Extremely weak	Scratched by thumbnail, gravel size lumps can be crushed between finger and thumb	0,6 – 1
Very weak	Scratched by thumbnail, lumps can be broken by heavy hand pressure, can be peeled easily by a pocket knife, crumbles under firm blows with point of geological hammer	1 – 5
Weak	Thin slabs, corners or edges can be broken off with hand pressure, can be peeled by a pocket knife with difficulty, easily scratched by pocket knife, shallow indentations made by firm blow with point of geological hammer	5 – 12,5
Moderately weak	Thin slabs, corners or edges can be broken off with heavy hand pressure, can be scratched with difficulty by pocket knife, hand-held specimen can be broken with single firm blow of geological hammer	12,5 – 25
Medium strong	Cannot be scraped or peeled with a pocket knife, specimen on a solid surface can be fractured with single firm blow of geological hammer	25 – 50
Strong	Specimen requires more than one blow of geological hammer to fracture it	50 – 100
Very strong	Specimen requires many blows of geological hammer to fracture it	100 – 250
Extremely strong	Specimen can only be chipped with geological hammer	> 250

NOTE Some extremely weak rocks will behave as soils and should be described as soils in accordance with para. 13.3 herein.

NOTE In cases of units of alternations of rocks with different strength, either a range of strength is given, form the weakest to the strongest, or a different strength for each rock.

NOTE Attribution of a strength range that exceeds an order of magnitude should be avoided (e.g. very weak to medium strong).

NOTE N.B.: this strength, which refers to the strength of the intact rock, should not be confused with the strength of the containing rock mass. The strength of the rock mass will obviously be lower and will be derived indirectly (e.g. with the utilisation of appropriate failure criteria).

13.2.3 Rock structure

Rock structure is reported in accordance with the provisions of para. 6.3 of the standard ELOT EN ISO 14689. Examples referring to the rock structure are given in Table 13.2.

Table 13.2 — Examples of terms which may be used in the description of rock

Sedimentary	Metamorphic	Igneous
Term	**Term**	**Term**
Bedded (see Table B.3) Interbedded Laminated Folded Massive Graded	Cleaved Foliated Schistose Banded Lineated Gneissose Folded	Massive Flow-banded Folded Lineated

For flat structure elements, the terms in Table 13.2 shall be used in conjunction with the terms in Table 13.3 (e.g. *very thin bedded*) or of the spacing of discontinuities in Table 13.6 (e.g. *very dense foliation*).

Table 13.3 — Terms to describe bedding thickness

Term	Spacing
Very thick bedded	> 2 m

Term	Spacing
Thick bedded	0,6 m – 2 m
Medium bedded	20 cm – 60 cm
Thin bedded	6 cm – 20 cm
Very thin bedded	2 cm – 6 cm
Thickly laminated	6 mm – 20 mm
Thinly laminated	< 6 mm

NOTE It is possible for the structural elements of the rock to constitute or not constitute discontinuities. In the event the structural elements are discontinuities then these should also be described as rock mass discontinuities (para. 13.2.10). As concerns this item, there is a differentiation between this document and Standard ELOT EN ISO 14689: in this document, the structure is assumed to be a characteristic of the rock and of the rock mass – in case the flat structural element is a discontinuity, while in ELOT EN ISO 14689 the structure is assumed to be a characteristic only of the rock mass.

13.2.4 Rock colour

Colour is described in accordance with the provisions of para. 5.1 of the standard ELOT EN ISO 14689 as follows: one term from each column of Table 13.4 is combined to identify the colour to be used .

Table 13.4 — Terms for lightness, chroma and hue which may be used in combination for colour description (examples)

Lightness	Chroma – Secondary descriptor	Hue – primary descriptor
Light Dark	Reddish Pinkish Orangish Yellowish Brownish Greenish Bluish Greyish	Red Pink Orange Yellow Cream Brown Green Blue White Grey Black

If deemed necessary, the colour differences in a rock may be pointed out and be described separately with the use of terms such as spots, specks, stripes etc.

EXAMPLES Light brownish-red, dark brown, yellowish-green with greyish-white stripes.

A colour collection can be especially useful in order to ensure compatibility among descriptions coming from different persons under different lighting conditions. The best lighting conditions are those outdoor or next to window in a bright or cloudy day.

13.2.5 Rock texture

Rock texture is described in accordance with the provisions of para. 44.2.4 of the standard BS 5930. Rock texture refers to the interrelation of the minerals from which it consists of, which may exhibit a preferable orientation. Common terminology for the rock texture description comprises the terms porphyritic, crystalline, crypto-crystalline, amorphous, glassy etc.

NOTE Macroscopic description of texture is only for special cases of crystalloid rocks, whose textural features are apparent on a microscopic scale.

NOTE An analytical description of rock texture may be found in the results of the petrographic analyses.

13.2.6 Grain / mineral size

The grain / mineral size is described in accordance with the provisions of para. 5.2 of the standard ELOT EN ISO 14689.

The subject size refers to medium size of the main grain / mineral forming the rock and it consists in a main diagnostic criterion for the determination of the petrographic type, e.g. sedimentary or igneous rocks (see Table A.1 of ELOT EN ISO 14689).

Usually, an estimation of the grain/mineral size by naked eye is sufficient however, a magnifying lens may be used for the identification of fine grained and amorphous rocks. It is possible that a separate description of the grain/mineral size and the rock matrix.

13.2.7 Rock weathering and alteration

Rock weathering / alteration is defined in accordance with the provisions of para. 5.4 of the standard ELOT EN ISO 14689. The result of the rock weathering / alteration shall be recorded as a primary element to identify the grade and extent of weathering / alteration of the rock and the materials left after the weathering / alteration process. The relevant information concerns the following characteristics:

- The grade and extent of the changes in the colour of the rock
- The initial (primary) unconfined compression strength of the rock (intact rock) and any changes related to weathering / alteration.

In order to have a description of the rock weathering/alteration, it is possible to apply adjectives to the terms of Table 13.5, such as: *partially discoloured, completely discoloured* or *slightly discoloured*. The three latter terms may also be used in combination such as: *completely discoloured* and *slightly disintegrated*.

Table 13.5 — Terms to describe weathering/alteration of rock materials

Term	Description
Fresh	No visible sign of weathering/alteration of the rock.
Discoloured	The colour of the original fresh rock is changed and is evidence of weathering/alteration. The degree of change from the original colour should be indicated. If the colour change is confined to particular mineral constituents, this should be mentioned.
Disintegrated	The rock material is broken up by physical weathering, so that bonding between grains is lost and the rock is weathered/altered towards the condition of a soil in which the original material fabric is still intact. The rock material is friable but the mineral grains are not decomposed.
Decomposed	The rock material is weathered by the chemical alteration of the mineral grains to the condition of a soil in which the original material fabric is still intact; some or all of the mineral grains are decomposed.

13.2.8 Unit name

The identification of the unit name derives from the characteristics of the rock (or rocks), such as origin (sedimentary (clastic, chemical or organic), igneous (plutonic, volcanic) or metamorphic), structure, texture, mineral composition, grain/mineral size, voids etc. An aid to rock identification is given in Table A.1 in Appendix A of the standard ELOT EN ISO 14689, as regards the description of basic sedimentary, igneous and metamorphic rocks.

The terminology of the lithological (petrographic) types and units is given in para. 13.5 (see also Geotechnical Baseline Report).

13.2.9 Geological unit

The geological unit is estimated during phase 2 and is finalised during phase 4, when it is recorded in the Macroscopic Description Borehole Sheets and the Borehole Logs. The geological formations of the wider area and their characteristics can be found in the geological maps of IGME (Institute of Geology and Mineral Exploration).

13.2.10 Rock mass discontinuities

Discontinuities are described in accordance with the provisions of para. 6.4 of the standard ELOT EN ISO 14689. Discontinuity is defined as a surface in the rock material, interrupting its continuity, the tensile or shear strength of which, across or along it, is lower than the strength of the rock material.

The following discontinuities' characteristics are described and recorded:

- Discontinuity type with respect to their genesis, as such: bedding plane, foliation, schistosity, joint, fault, shear, cleavage, incipient fracture, induced fracture, etc.
- Orientation: only the dip of discontinuity.
- Spacing, terminology in accordance with Table 13.6.
- Discontinuity roughness: The terms which are used are: *planar, undulating and stepped* in conjunction with terms: *rough, smooth* and *striated, slickensided.*
- Discontinuity aperture based on Table 13.7.
- Infilling: the discontinuity infill is reported, e.g. *soil*, minerals such as *calcite, quartz, epidote, chlorite, clay minerals, oxides, hydroxides, gouge* or *breccia* etc. As the case may be and wherever it is relevant, the shear strength and the swelling potential of the infill will also be described.

Table 13.6 — Terms to describe discontinuities spacing

Term	Spacing
Extremely close	< 2 cm
Very close	2 cm – 6 cm
Close	6 cm – 20 cm
Medium	20 cm – 60 cm
Wide	0,6 m – 2 m
Very wide	> 2 m

Table 13.7 — Terms for the description of discontinuity aperture

Term	Aperture
Very tight	< 0,1 mm
Tight	0,1 mm – 0,25 mm
Partly open	0,25 mm – 0,5 mm
Open	0,5 mm – 2,5 mm
Moderately wide	2,5 mm – 10 mm
Wide	1 cm – 10 cm
Very wide	10 cm – 100 cm
Extremely wide	> 1 m

The remaining characteristics of discontinuities (persistence, seepage characteristics, number of sets and rock block size, see paragraphs 6.4.4, 6.4.5, 6.4.9 and 6.4.10 of ELOT EN ISO 14689) are described only in rockmass occurrences and cannot be possibly described in borehole cores.

13.2.11 Core recovery and core fracture state of rock mass

Fracture state is described with the following terms, in accordance with the provisions of para. 7 of the standard ELOT EN ISO 14689 (Figure 13.1).

- Total core recovery (TCR) is the length of core recovered (both solid and non-intact), in the core run, expressed as a percentage.
- Solid core recovery (SCR) is the length of solid core recovered in the core run, where solid core has at least one full diameter, expressed as a percentage.
- Rock quality designation (RQD) is the summed length of solid core pieces each with at least one full diameter recovered in the core run where each piece is at least 100 mm long between natural fractures, expressed as a percentage.

- Fracture index (If) is the spacing between natural fractures along the core in zones of uniform character, not per core run. The If can usefully be given as a minimum, mode and maximum values within the zone.

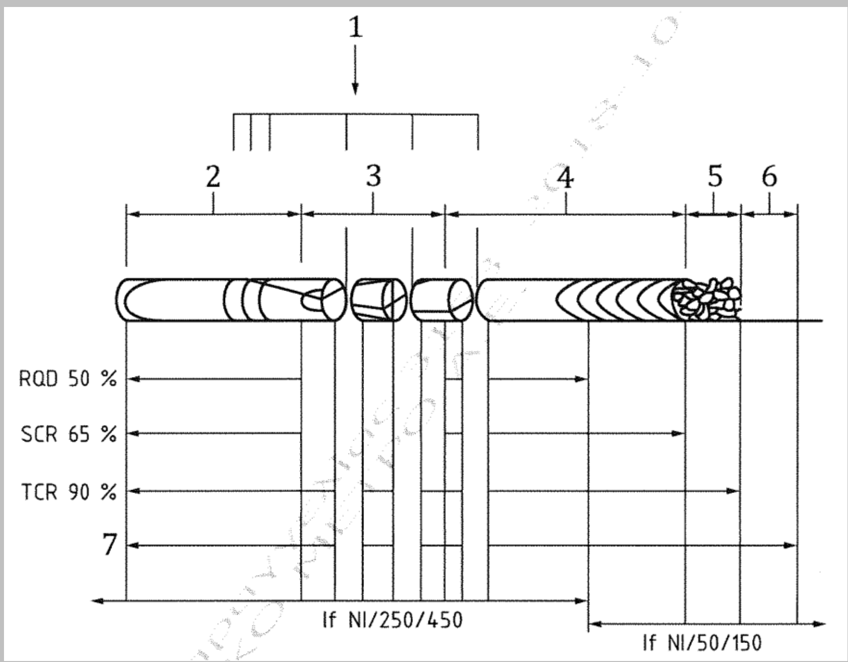
NOTE Solid core has a full diameter which is not interrupted by discontinuities but not necessarily a full perimeter and its length is measured along the core axis.

NOTE Drilling induced fractures should not be considered for the calculation of the RQD and SCR.

NOTE With respect to the Alpine bedrock units, RQD should be assigned only in rocks, in rock masses which contain discontinuities which can be described and in rock masses which are described as heavily fractured. RQD assignment should be avoided for rock masses within which heavily sheared and soil-like units are dominant such as clayey schist.

NOTE As regards Neogene - Quaternary units, RQD should be assigned only on rock materials.

Figure 13.1 — Application of fracture state terms for rock cores



<u>Legend of Figure B.1:</u>

1. drilling-induced fractures
2. solid core (at least one full diameter)
3. no single full diameter
4. solid core (at least one full diameter)
5. non-intact
6. no recovery
7. core run

13.2.12 Rock mass weathering

Rock mass weathering is described in accordance with the provisions of para. 6.5 of standard ELOT EN ISO 14689.

Rock mass weathering is described on the basis of the distribution and quantitative relation between fresh rock and discoloured, disintegrated or decomposed rock in conjunction with the weathering in discontinuities. The weathering process finally converts the rock in soil and as such, the rock mass weathering description is carried out in relation with the existence of three "phases" within the rock mass: rock, rock and soil, soil.

For the description of the rock mass weathering the following six-stage scale of Table 13.8 is used.

Table 13.8 — Scale of weathering stages of rock mass

Term	Description	Grades
Fresh	No visible sign of rock material weathering; perhaps slight discolouration on major discontinuity surfaces.	0
Slightly weathered	Discolouration indicates weathering of rock and discontinuity surfaces.	1
Moderately weathered	Less than half of the rock is decomposed or disintegrated. Fresh or discoloured rock is present either as continuous framework or as core stones.	2
Highly weathered	More than half of the rock is decomposed or disintegrated. Fresh or discoloured rock is present either as a discontinuous framework or as core stones.	3
Completely weathered	All of the rock is decomposed or disintegrated to soil. The original mass structure is still largely intact.	4
Residual soil	All of the rock is converted to soil. The mass structure and material fabric are destroyed. There is a large change in volume, but the soil has not been significantly transported.	5

NOTE Table 13.8 gives a typical weathering classification scale and may not be applicable to all rock mass types. Annex B of Standard ELOT EN ISO 14689 presents a more general weathering classification scale as concerns rock and rock mass.

NOTE Weathering/alteration description should be carried out with particular attention since, given that it is discharged on borehole cores which do not necessarily reflect the true state of the rock mass.

13.2.13 Additional information

They refer to characteristics which are not included in elements 1 to 8, para. 13.2.1 (e.g. rock degradation, in line with paragraph 5.6 of ELOT EN ISO 14689, carbonate content for carbonate rock, in line with paragraph 5.5 of ELOT EN ISO 14689), or to characteristics which are included in elements 9 to 11 of the same paragraph and it is deemed necessary to be stressed in the unit description field.

NOTE In cases of sieve analyses in soil-like zones of rock masses, these are not required to be described in the unit description field as additional information and they will be reported in the respective Borehole Log column.

13.3 Engineering geological description of soil units

13.3.1 General

The description of the soil unit shall correspond to the description of the lithological type of which it is composed. In case of more than one lithological type, the description shall be a synthesis of the descriptions of the composing lithological types. The methodology of the engineering geological description of soils will, in principle, follow the standards ELOT EN ISO 14688-1 and 2.

In the unit description field the following elements will be reported in the displayed sequence:

1. Consistency or relevant Density.
2. Discontinuities.
3. Bedding.
4. Colour.
5. Soil strength.
6. Unit name (base group name in uppercase) and symbol (in parenthesis).
7. Geological formation (in parentheses, in uppercase).
8. Size, shape and mineral composition of coarse fractions.
9. Shape and description of very coarse fractions.
10. Maximum size of very coarse soils.
11. Additional characteristics.

NOTE Description of elements 1 to 7 is reported in one sentence. Items 8 to 11 are reported in one or more sentences. Items from the above list not relevant to the characteristics of the soil unit shall be deleted.

NOTE In case of a unit with alternations of different soil layers, when the layers are distinct they should be described separately regardless of being united as a unified unit. Whenever the alternations are of such a scale that does not allow the distinction of the composing layers, the description will be unified. See also para. 7.3 of standard ELOT EN ISO 14688-1.

EXAMPLEMedium dense, light ash-green, slightly clayey GRAVELY SAND widely graded with stones (gr-Sa-w) (QUATERNARY FLUVIO-TERRENTIAL DEPOSITS). Thin-grained, quartz sand, coarse and medium well-rounded gravels of limestone and schist composition. Well-rounded stones of moderately strong, pink-ash, fresh LIMESTONE.

Guidelines are given below for the description of the individual characteristics which are examined.

13.3.2 Consistency or relative density

Consistency is determined at phase 2, in fine grained (cohesive) soils by a field macroscopic estimation in accordance with para. 6.1.6 of the standard ELOT EN ISO 14688-1 and is corrected, if necessary, at stage 4 based on laboratory test results (determination of Consistency Index $I_C = (w_L - w)/I_p$), in accordance with para. 5.5 of the standard ELOT EN ISO 14688-2.

The terminology as regards the consistency and the respective Consistency Index I_C is given in Table 13.9.

Table 13.9 — Consistency terms for fine grained soils

Term	**Consistency description definition**	**Consistency index I_C**
Very soft	Finger can be easily pushed in up to 25 mm. Soil exudes between the fingers when squeezed in the hand.	< 0,25
Soft	Finger can be pushed in up to 10 mm. Soil can be moulded by light finger pressure.	0,25 – 0,50
Firm	Thumb makes an impression easily. Soil cannot be moulded by fingers, but rolls in the hand to 3 mm thick threads without braking or crumbling.	0,50 – 0,75
Stiff	Soil can be indented slightly by thumb. Soil crumbles and breaks when rolling to 3 mm thick threads but is still sufficiently moist to be moulded to a lump again.	0,75 – 1,00
Very stiff	Soil can be indented by thumb nail. Soil cannot be moulded but crumbles under pressure. Many desiccated soils fall in this class.	> 1,00

NOTE The above subdivisions of consistency may be approximate, especially for low plasticity cohesive materials (e.g. silts).

Relative density is determined in coarse grained soils, by laboratory tests (determination of Density Index $I_D = (e_{max} - e) / (e_{max} - e_{min})$), in accordance with para. 5.2 of ELOT EN ISO 14688-2. Additionally, relative density may be estimated by in situ tests (e.g. Standard Penetration Test SPT). The terminology as regards the relativedensity of coarse grained soils is given in Table 13.10.

Table 13.11 — Relative Density of coarse grained soils

Term	**Density index I_D (%)**	**$(N_1)_{60}$ [1]**
Very loose	0 – 15	0 – 3
Loose	15 – 35	3 – 8
Medium dense	35 – 65	8 – 25
Dense	65 – 85	25 – 42
Very dense	85 – 100	42 – 58

NOTE 1 Normalised blow count $(N_1)_{60}$ for normally consolidated natural sands. For the determination of the normalised blow count see ELOT EN ISO 22476-3.

13.3.3 Discontinuities

The discontinuities' types are described as: fissure, shear plane, fault, and induced fracture. In addition to the above, the term "fissured" states that the soil breaks along slippery discontinuities and the term 'sheared' states that the soil breaks along slickensided shear planes.

Other discontinuities related features are described in accordance with para. 13.2.10 herein.

13.3.4 Bedding

Bedding is described in accordance with para. 13.2.3 herein. Bedding thickness is described in accordance with Table 13.3 herein.

Bedding may appear as parallel surfaces (planar bedding) but may also appear in other forms as a result of sedimentation processes, e.g. cross-bedding, graded bedding etc. Bedding planes may or may not constitute discontinuities, as the case may be.

13.3.5 Colour

Colour is described in accordance with para. 13.2.4 herein. Colour description should be carried out on a fresh exposure of the soil as, in some cases, the soil colour changes rapidly when in contact with air. Furthermore, alterations of the original soil colour due to oxidation or drying should be recorded.

13.3.6 Strength of cohesive soils

The terminology regarding the undrained shear strength is given in Table 13.11.

Table 13.11 — Undrained shear strength of fine soils

Strength	Undrained shear strength C_u (kPa)	Equivalent unconfined compressive strength q_u (kN/m^2)
Extremely low	< 10	< 20
Very low	10 – 20	20 – 40
Low	20 – 40	40 – 80
Medium	40 – 75	80 – 150
High	75 – 150	150 – 300
Very high	150 – 300	300 – 600
Extremely high	> 300	> 600

NOTE Materials with undrained shear strength greater than 300kPa may behave as weak rocks and may be described in accordance with para. 13.2.

13.3.7 Unit name

Initially, the soils shall be classified into groups according to the Hellenic Soil Classification System HSCS (para. G).The name of the unit shall correspond to the name of the soil group wherein the soil sample is classified and shall be recorded as follows: the name of the base group (see para. 18.10.3) wherein the soil is classified is reported in uppercase and the other characteristics (secondary fractions, tertiary constituents) are reported in lowercase are reported in lowercase. At the end of the name, the soil group symbol is given in parentheses.

EXAMPLEslightly calcareous gravely sandy, slightly organic, HIGH PLASTICITY CLAY ((or)CI-H.

During phase 2, there is a macroscopic examination of the soil unit(determination and per weight estimate of the primary and secondary fractions, determination of probable tertiary constituents, plasticity of fines (if applicable) and determination of organics and/or calcium carbonate (if applicable) see ELOT EN ISO 14688-1, followed by the application of the HSCS criteria HSCS (see para. 18.10). In case the unit is made up by more than one lithological type, macroscopic examination for each type is carried out, while the name of the unit shall result as a synthesis of the name of the individual lithology types.

During phase 4 and after the classification tests, the name of the units shall be corrected – if required, on the basis of the results of these tests.

The codification of the soil units (e.g. for use in laboratory test forms, summary tables of results, etc.) may follow the specifications of para. 18.12.

13.3.8 Geological formation

The content of the description concerning rock units (para. 13.2.9) applies.

13.3.9 Size, shape and mineral composition of coarse fractions

Particle *size* for gravel and sand is recorded based on the results of the classification tests, in line with the terminology included in Table 13.12 (see also Table 18.1).

Table 13.12 — Terms for coarse fraction size

Term (EN)	Particle size (mm)
Coarse gravel	> 20 to ≤ 63
Medium gravel	> 6,3 to ≤ 20
Fine gravel	> 2 to ≤ 6,3
Coarse sand	> 0,63 to ≤ 2
Medium sand	> 0,2 to ≤ 0,63
Fine sand	> 0,063 to ≤ 0,2

The *shape* of the particles shall be described in line with para. 6.1.2 of ELOT EN ISO 14688-1. Only the shape of the gravels shall be described. The following terms will be used: *very angular, angular, sub-angular, sub-rounded, rounded and well-rounded* in combination with the terms *cubic*, *flat* or *tabular* and *elongated*, as well as *rough* and *smooth* (see also Figure 17 of BS 5930).

Mineral composition will be described in line with paragraph 6.1.4 of ELOT EN ISO 14688-1. The rock of origin (*limestone gravel, gneiss gravel* etc.) shall be described for gravel, while the minerals of origin (*quartzitic sand, muscovite sand* etc.) shall be described, if possible, for sand.

13.3.10 Shape and description of very coarse fractions

The shape of the very coarse fractions (stones, boulders and large boulders) shall be described in line with para. 6.1.2 of ELOT EN ISO 14688-1 (for the relevant terms see para. 13.3.9). Moreover, the rock from which coarse fractions are composed shall be described in line with the content of paragraphs 13.2.2 to 13.2.8.

EXAMPLE Rounded, elongated and smooth stones of medium strong, solid, pink-ash, crystalline, fresh limestone and of moderately weak, ash-green, discoloured green limestone with schistocity.

EXAMPLE Sampling in soils with very coarse fractions is not representative *per se*. In this case, the following description shall be made: "*very coarse fraction – no representative sampling*", followed by the recording of the position (depths) and the description of the very coarse fractions, as presented above.

13.3.11 Maximum size of very coarse fractions

In case of very coarse fractions, the maximum particle size D_{max} shall be recorded.

13.3.12 Additional characteristics

The additional characteristics may include any characteristics of the soil unit which are not included in paragraphs 13.3.2 to 13.3.11 above and which are deemed advisable to be included in the description, e.g.:

- special macroscopic characteristics: existence of uneven concretions of calcium carbonate at the size of coarse sand, hydroxide impregnation,
- grading: in coarse soils with fine fraction < 15 %, the uniformity coefficient (C_U, para. 18.3.19) is the criterion for the classification of coarse soils (see para. 18.10.4 and Table 18.3) and is recorded in the relevant classification form (see Figure 18.4); however the curvature coefficient can be recorded in the description field as additional item (C_C, para. 18.3.18),
- degree of decomposition of peat, see para. 6.1.10 of ELOT EN ISO 14688-1,
- sensitivity in fine soils (see para. 5.4 of ELOT EN ISO 14688-2),
- water content (w, see para. 18.3.17),
- dry density (γ_d),
- activity index (I_A) in fine soils (see para. 8.3.6),
- mineral composition (after the execution of mineral analyses, T37 in Table 8.1),
- saturation point (S),
- permeability (k, see para. 7.5.4),
- compressibility coefficient (C_c, see para. 3.2 of ELOT EN ISO 14688-2),
- swelling coefficient (C_s),
- collapse potential in loess.

13.4 Special cases and made ground

During sampling, when voids, ducts and other structures are encountered, these will be described as units and shall be classified under the geological unit "Man-made Deposits".

Description of man-made materials within the Artificial Deposits shall be effected in line with paragraph 18.8 (see also 6.2.4 of Standard ELOT EN ISO 14688-1).

13.5 Designation and coding of lithological types and engineering geological units

13.5.1 Petrographic types and rocky engineering geological units

The purpose of the terminology referring to the petrographic types in the following Tables is to assist the geologist in the description of borehole cores by choosing, on the basis of the macroscopic description one executes, one of the petrographic types in Tables 13.13 and 13.14. These Tables include the pertographic types described in the framework of earlier ground investigations of AM. This terminology is by no means binding to the geologist which carries out the macroscopic description to choose from one of these names.

Table 13.13 presents the AGS field code related to the petrographic type, which is used in the transmittal of the digital AGS files (Appendix E).

Table B.13 — Petrographic types

s/n	Term (EN)	ROCK_DESC
1	BRECCIA	BREC
2	Calcareous BRECCIA	BRECCC
3	CONGLOMERATE	CONG
4	Calcareous CONGLOMERATE	CONGCA
5	GRIT	GRIT
6	SANDSTONE	SDST
7	Calcareous SANDSTONE	SDSTCA
8	SILTSTONE	SLST
9	Calcareous SILTSTONE	SLSTCA
10	Gravelly SILTSTONE	SLSTGR

s/n	Term (EN)	ROCK_DESC
11	CLAYSTONE	CST
12	Calcareous CLAYSTONE	CSTCA
13	Gravelly CLAYSTONE	CSTGR
14	MARL	MRL
15	Calcareous MARL	MRLCA
16	MARLY LIMESTONE	MRLMST
17	Thin-bedded MARLY LIMESTONE	MRLMSTTB
18	Intraclastic MARLY LIMESTONE	MRLMSTBR
19	Karstic MARLY LIMESTONE	MRLMSTCR
20	LIMESTONE	LMST
21	Intraclastic LIMESTONE	LMSTBR
22	Karstic LIMESTONE	LMSTCR
23	DOLOMITE	DL
24	METASANDSTONE	MSDST
25	Calcareous METASANDSTONE	MSDSTCA
26	METASILTSTONE	MSLST
27	Calcareous METASILTSTONE	MSLSTCA
28	SHALE	SHALE
29	PHYLLITE	PHYL
30	Calcareous PHYLLITE	PHYLCA
31	Chlorite SCHIST	SCHCL
32	Chlorite quartzitic SCHIST	SCHCLQ
33	Chlorite epidote SCHIST	SCHCLE
34	Calcareous SCHIST	SCHCA
35	Calcareous chlorite SCHIST	SCHCACL
36	Mica quartzitic SCHIST	SCHMQ
37	SERPENTINITE	SEPITE

In the case of variable rock units, the terms are derived from the combination and participation percentages of the petrographic types listed in Table 13.14. Table 13.14 also presents the AGS field code related to the engineering geological unit to be used in the transmittal of the digital AGS files (Appendix E).

Table 13.14 — Terminology for variable rock unit

Participation (%) of the primary petrographic type (A)	Participation (%) of the secondary petrographic type (B)	Name of unit	GEOL_LEG
90	10	A with rare intercalations B [1] A with thin intercalations B [1]	A9B1
70	30	A with intercalations B	A7B3
50	50	Alteration A and B	A5B5

NOTE 1 Depending of the structure of the unit.

13.5.2 Soil lithological types and engineering geological units

The terminology referring to the soil lithological types (Table 13.15) is identical with the names of the basic groups of soil of the soil classification HSCS (Table 18.2).

Table 13.15 — Soil lithological types

s/n	Term (EN)	ROCK_DESC
1	GRAVEL	GR
2	SANDY GRAVEL	GRSA
3	GRAVELLY SAND	SAGR
4	SAND	SA

s/n	Term (EN)	ROCK_DESC
5	SILTY GRAVEL	GRSI
6	CLAYEY GRAVEL	GRCL
7	SILTY SAND	SASI
8	CLAYEY SAND	SACL
9	SILT	SIL
10	MEDIUM PLASTICITY SILT	SIM
11	HIGH PLASTICITY SILT	SIH
12	VERY HIGH PLASTICITY SILT	SIV
13	LOW PLASTICITY CLAY	CLL
14	MEDIUM PLASTICITY CLAY	CLM
15	HIGH PLASTICITY CLAY	CLH
16	VERY HIGH PLASTICITY CLAY	CLV

In the case of variable soil units, the names mentioned in Table 13.14 can be used.

13.6 Names for special cases of units

Table B.16 presents the names of special cases of materials and the corresponding AGS field code which is used in the transmittal of the digital AGS files (Appendix E).

Table 13.16 — Special cases of engineering geological units

s/n	Term (EN)	GEOL_LEG
1	ASPHALT	ASPHALT
2	PAVEMENT	PAVE
3	CONCRETE	CONCR
4	WEATHERING MANTLE	WRMATL
5	SHEAR ZONE	SHEAR
6	CATACLASITE	CATACLASITE
7	SOIL MATERIALS (undifferentiated)	FILL
8	VOID	VOID
9	Karstic VOID	CRVOID
10	FILLED CARSTIC VOID	CRFILL
11	QUARTZ	QUARTZ
12	CALCITE	CALCITE

14 APPENDIX C: Rock mass classification systems

14.1 General

As regards rock mass classification, the Contractor shall utilize the Geological Strength Index (GSI) system and any other (if necessary) classification system.

The Rock Mass Classification system may be correctly applied on the borehole cores requires category A sampling, according to the provisions of para. 6.7.2. It is obvious that special attention should be paid to the implementation of rock mass classification systems on disturbed cores (category B sampling) since in these cases there is inevitably increased uncertainty as to the estimation of individual parameters as to the rock mass structure (RQD, Jspacing and Jcondition for MR, rock mass structure and discontinuities condition for GSI). Therefore, the Geologist involved in the preparation of the rock mass classification will decide on the level of uncertainty introduced based on the sampling condition and will subsequently, depending on the case, implement the rock mass classification with caution, or proclaim that its implementation is not possible.

14.2 Geological Strength Index - GSI

14.2.1 General

The Geological Strength Index (GSI) is based on the estimation of lithology, structure and rock mass discontinuities' condition. This paragraph refers to the application of the GSI both during the borehole core description and the Project excavation faces (tunnel faces, excavation and pits' slopes etc.).

14.2.2 Application of the Geological Strength Index

For the application of the Geological Strength Index, the following bibliography is proposed. It is pointed out that due to the continuous assessment of data and information ensuing from the application of the GSI on technical projects, the latest bibliography is updated based on the relevant experience and therefore are more important.

1. Marinos P., Marinos V., Hoek E., 2007. *Geological Strength Index (GSI). A characterization tool for assessing engineering properties for rock masses*, In: *Proceedings of the Rock Mass Classification Workshop, publ: Department of Earth and Human Services*, NIOS, Information IC9498, Information circular 2007, Vancouver.

2. Marinos V, Marinos P, Hoek E., 2005. *The geological Strength index: applications and limitations.* Bull. Eng. Geol. Environ., 64:55-65.

3. Marinos, B., Marinos, P., Hoek, E., 2004. *Geological Strength Index GSI. Implementation, recommendations, restrictions and fields of change according to rock type*. Bulletin of the Geological Society of Greece, XXXVI. Proceedings of the 10th International Conference, Thessaloniki 2004.

4. Marinos P, Hoek E., 2001. *Estimating the geotechnical properties of heterogeneous rock masses such as flysch*. Bull. Eng. Geol. Environ. 60:82–92.

5. Marinos P, Hoek E., 2000. *GSI: a geologically friendly tool for rock mass strength estimation*. In: *Proceedings of the GeoEng2000 at the international conference on geotechnical and geological engineering*, Melbourne, Technomic publishers, Lancaster, 1422–1446.

6. Hoek E, Marinos P, Benissi M., 1998. *Applicability of the geological strength index (GSI) classification for weak and sheared rock masses - the case of the Athens*

schist formation. Bull. Eng. Geol. Environ. 57(2):151–160

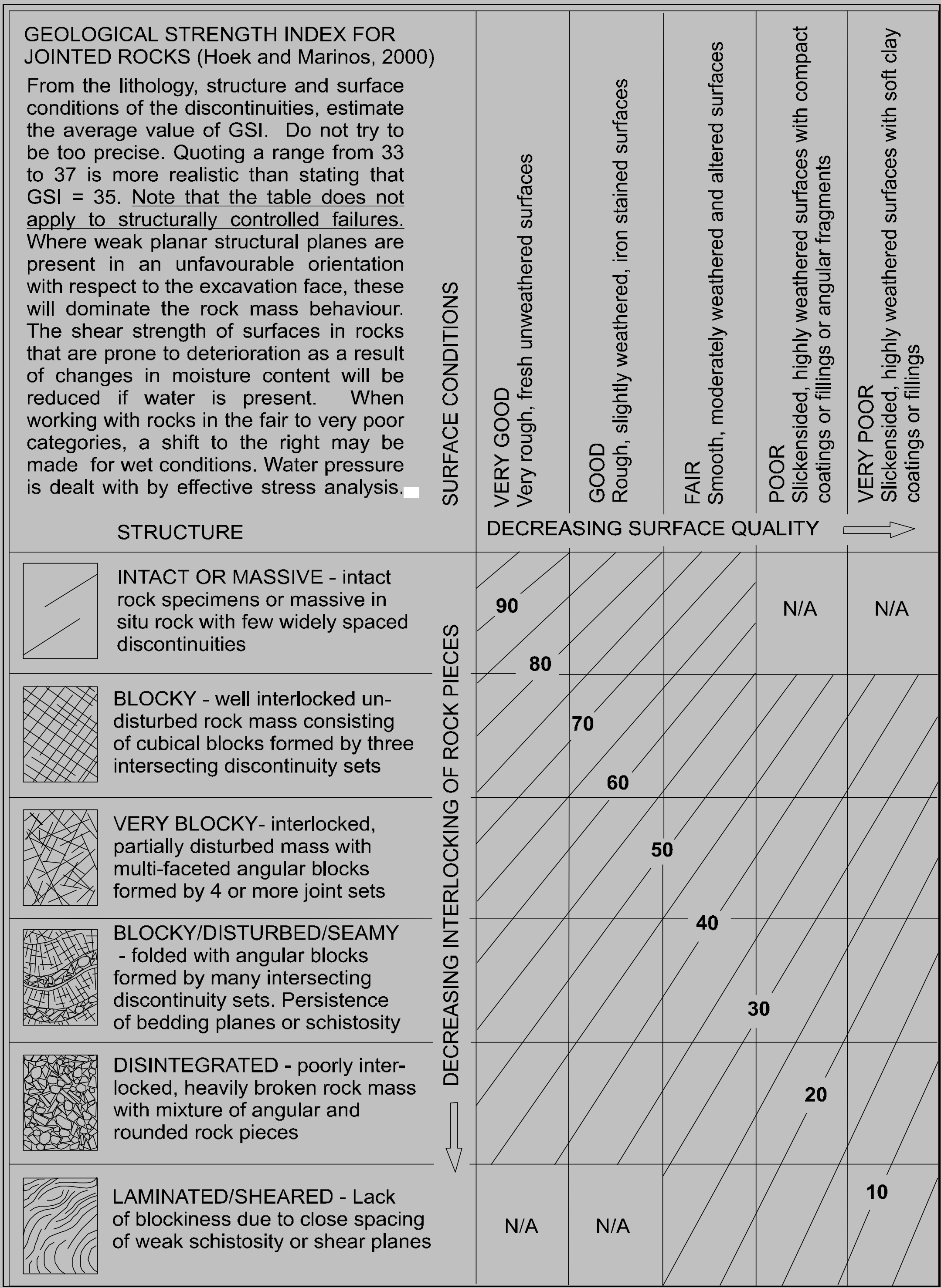
14.2.3 Recommendations for the application of the Geological Strength index

Special attention should be paid during the application of the GSI to the following points, according to the provisions of the relevant bibliography presented in above:

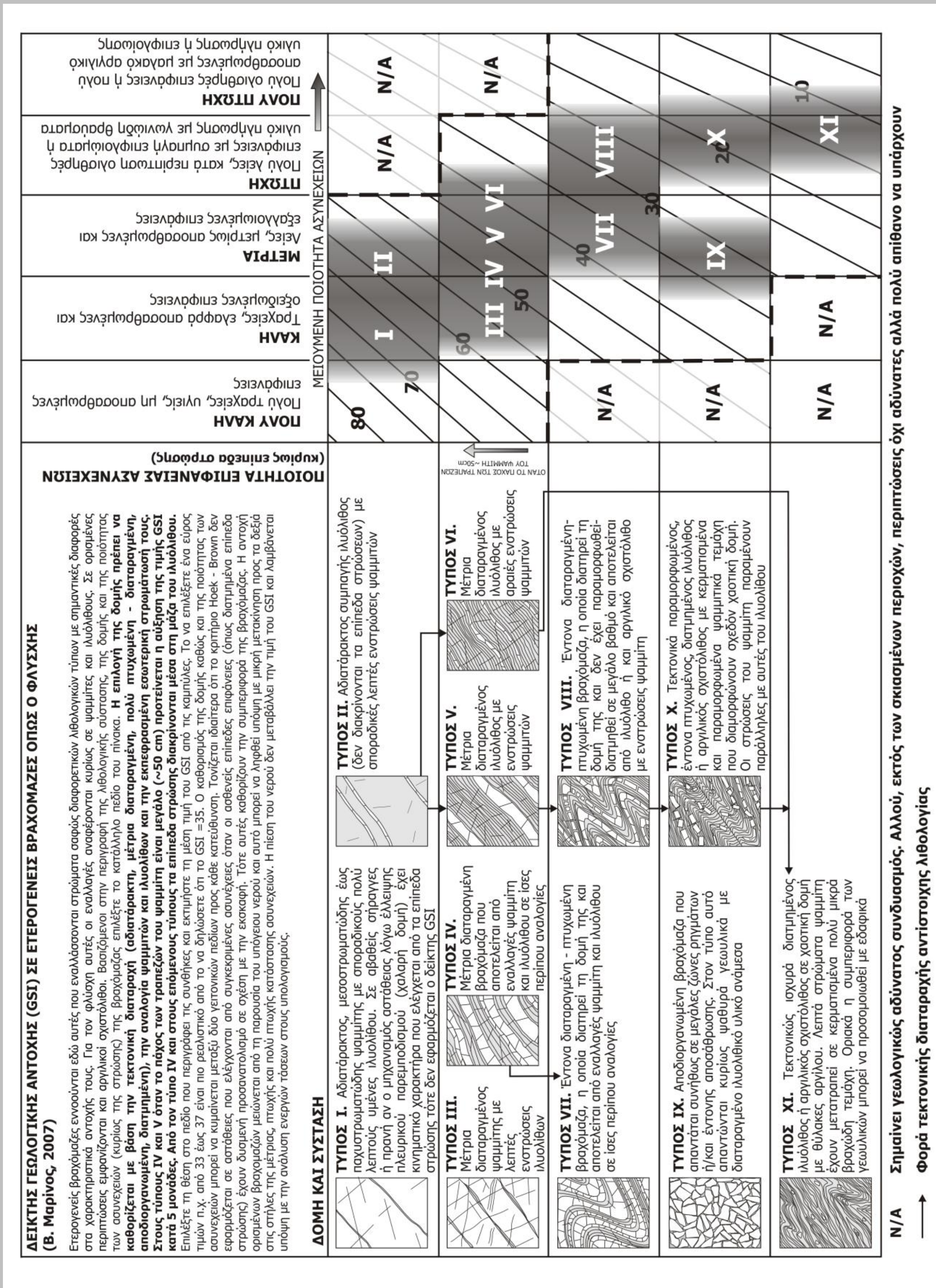
- Application of the GSI to borehole cores: During the engineering geological description of borehole cores the punctual borehole information should be protruded at the Project scale in order to assess the rock mass GSI value more properly. For this reason, a co-assessment of the adjacent boreholes should be made in order to appreciate the rock mass structure at the Project scale. Moreover, the attribution of GSI values to core sections less than 1m long should be avoided; however, the application of the GSI to lengths representative of the geomaterial at the Project scale should be preferred. In general, it is safe to attribute GSI values to distinct strata, as described. It is noted that the GSI is on its own a criterion of stratum segregation since different GSI values are obviously due to different structure or discontinuities' conditions and consequently to different mechanical characteristics. Therefore, the strata to which the GSI is attributed should generally coincide with the strata resulting from the engineering geological description.
- Application of the GSI to heterogeneous rock masses: Heterogeneous rock masses are considered those on which there are alternating strata of different lithological types with significant differences to their mechanical characteristics. As to these rock masses, the application of the relative chart (GSI for heterogeneous rock masses such as flysch, V. Marinos, 2007). In any case, the application of the "classic" GSI chart (Geological Strength Index for jointed rock masses, Hoek and Marinos, 2000) is not excluded, taking into account the experience of the person who describes. In the second case, the member of the heterogeneous rock mass which is the least adequate will be considered as discontinuity infill and, therefore, the discontinuities' condition will have to range from poor to very poor or, marginally, fair depending on the layer's thickness of the least adequate member, its lithology and its degree of tectonism.
- Application of the GSI to rock masses with few and infrequent discontinuities (usually rock masses of recent geological age): The use of the GSI on rock masses with few and infrequent discontinuities, whose effect on their behaviour as to the deformation is negligible on a Project scale, should be avoided. In these cases, the intact rock samples are representative of the rock mass and, therefore, strength and deformation parameters can directly result from laboratory tests on intact rock samples.
- Intact rock unconfined compressed strength is not taken in consideration in the GSI classification, since it is included as an independent parameter during the application of the Hoek-Brown failure criterion. Based on the above, the geologist who proceeds with the classification should be particularly careful not to confuse the sense of the rock mass structure with the intact rock strength. Therefore, rock masses with very weak to weak intact rock (e.g. metasiltstone) are attributed GSI values throughout the entire range provided for in the respective charts, depending on the structure and the condition of their discontinuities, but not necessarily poor values.

The relevant GSI charts which are applicable to the anticipated rock masses in the Project area are presented below.

14.2.4 Geological strength index for jointed rock masses (Hoek and Marinos, 2000)



14.2.5 Geological Strength index (GSI) for heterogeneous rock masses such as flysch (V. Marinos. 2007)



14.3 Mass Rating - MR

14.3.1 General

The Rock Mass classification system, referred to as Mass Rating - MR system is based on critical geological and geotechnical parameters of the rock mass. This para. refers to the application of MR during the borehole core description.

14.3.2 The MR System basis

The MR system is based on the Rock Mass Rating - RMR classification system as that was developed by Prof. Z. T. Bieniawski ([1] & [2]) and it has been adapted to accommodate the Athenian Schist conditions.

For the adaptation, discussed and agreed between Attiko Metro AE and Dr Brian Hawkins of Bristol University, U.K, consultant for the Olympic Metro Consortium in 1994, the accumulated up to that point experience and the existence of certain very low strength, extreme tectonism, low metamorphism and intense weathering members of the Athens Schist Group were taken into account.

The said system focuses on a further detailed subdivision of RQD and Spacing of Discontinuities (Jspacing) ratings, below Bieniawski’ s corresponding lower boundary values [1]. In doing so, the MR system recognizes the need for greater discernibility throughout the poor and very poor rock mass classes (RMR Class IV and V), that is the frequently in Athens encountered conditions at the lowest RMR boundary values. This need stems from the nature of some members of the Athenian Schist Formation which present a variety of very closely spaced intercalations of thinly to very thinly bedded metasandstone and slickensided metasiltstone and shale and/or very severely sheared, fractured and folded layers with discontinuities filled with clayey gouge and/or highly weathered and extremely tectonised layers.

14.3.3 Application of the MR System

14.3.3.1 General

The following six parameters are used to classify a rock mass using the MR system:

1. Unconfined compressive strength of intact rock.
2. Rock quality designation (RQD).
3. Spacing of discontinuities.
4. Condition of discontinuities.
5. Groundwater conditions.
6. Orientation of discontinuities.

Similarly to the RMR system, the rock mass may be divided, if necessary, into a number of structural / geotechnical zones such that certain features are more or less uniform within each zone, as determined by detailed technical-geological mapping.

14.3.3.2 Unconfined compressive strength of intact rock

The unconfined compressive strength of the intact rock (UCS) is defined based on laboratory tests. The in situ measurement of the UCS is made as per para. 13.2.1 herein. Additional strength measurement methods are provided in the bibliography (see [6]). In any case, such measurements of the UCS value cannot substitute the aforementioned laboratory test results.

In the case of highly or completely weathered rock, sections of less weathered material are not considered to be the corresponding intact rock material but rather the rocky relict of the original material.

14.3.3.3 Rock Quality Designation (RQD)

RQD identification is in compliance with the provisions of para. 13.B.2.10.

In Bieniawski's classification, a minimum value of 3 is assigned for any RQD less than 25%. The adapted scheme assigns the value of 3 to RQD = 25 %, the value of 2 to 25% > RQD > 10 %, the value of 1 to RQD < 10 %.

14.3.3.4 Spacing of discontinuities (Jspacing)

When inspecting a sampled set of borehole cores prevailing sets of discontinuities will be identified, though their arrangement cannot be ascertained. The range of values for the spacing between those sets of discontinuities is given in the MR form.

For the case of thinly to very thinly bedded or foliated (slickensided), layers, extensive shear zones and strongly disturbed highly weathered strata etc., further subdivisions below the Bieniawski value of 5 are used. Hence for 5 cm > Jsp > 2.5 cm a value of 3 is assigned. For 2.5 cm > Jsp > 1.0 cm a value of 2 is assigned, while for Jsp < 1.0 cm a value 1 is assigned.

14.3.3.5 Condition of discontinuities (Jcondition)

The condition of the sets of discontinuities identified will be determined by means of section "Guidelines for the classification of discontinuities" in the MR form. Particular attention should be given to discontinuities filled with fine grained material (such as clay and silt). A rough estimate is also provided in the relevant A.4 section of the form, based on description data.

14.3.3.6 Groundwater conditions

The groundwater conditions of a borehole cannot be known with certainty for its entire length when examining its cores. Thus, a convention is made to set groundwater conditions parameter equal to ten (10) assuming damp conditions uniformly prevailing.

14.3.3.7 Orientation of discontinuities

In sections B and F of the MR form the rating adjustment for discontinuity orientations and the effects of discontinuity strike and orientation in tunnelling (per Wickham et al. [6]) are given. These are not used when logging cores.

14.3.3.8 Limitations

It must be emphasized that for all applications involving the selection of the direct tunnel support, determination of loads and deformability, it is the actual MR value that must be used and not the rock mass class within the MR value falls and this is because the MR system is very sensitive to the importance of individual parameter changes.

14.3.4 Bibliography

1. Bieniawski Z. T., 1979, *The Geomechanics Classification in Rock Engineering Applications*, Proc. 4th Int. Congr. Rock Mech., ISRM, Montreux, Vol. 2, pp 41 - 48.
2. Bieniawski Z. T., 1989, Engineering Rock Mass Classifications, A Complete Manual for Engineers and Geologists in Mining, Civil and Petroleum Engineering, John Wiley & Sons, USA, ISBN: 0-471-60172-1.
3. Brady B. H. G., Brown E. T., 1985, *Rock Mechanics for Underground Mining,* George Allen & Unwin, London, ISBN: 0-04-622004-6.
4. ISRM Suggested Methods, 1981, *Rock Characterisation Testing and Monitoring*, Brown E. T. (ed.), Pergamon Press, UK, ISBN: 0-08-027309-2.
5. Geological Society of London, Professional Handbook Series, 1991, *The Field Description of Engineering Soils and Rocks*, Open University Press, UK, ISBN : 0-335-15208-2.
6. Wickham G. E., Tiedemann H. R., Skinner E. H., 1972, *Support Determination Based on Geologic Predictions*, Proc. Rapid Excav. Tunnelling Conf., AIME, New York, pp 43 - 64.

14.3.5 Mass Rating System (MR) Form

Mass Rating System (MR) [1]

Table A: Classification parameters and their ratings

	Parameter		Range of values							
1	Strength of intact rock (MPa)	Point load	N/A			1 - 2	2 - 4	4 - 10	> 10	
		σ_{ci}	< 1	1 - 5	5 - 25	25 - 50	50 - 100	100 - 250	> 250	
		Rating	***0***	***1***	***2***	***4***	***7***	***12***	***15***	
2	RQD (%)		< 10	10 - 25	25	25 - 50	50 - 75	75 - 90	90 - 100	
		Rating	***1***	***2***	***3***	***8***	***13***	***17***	***20***	
3	Spacing of discontinuities (mm)		< 10	10 - 25	25 - 50	50 - 60	60 - 200	200 - 600	600 - 2000	> 2000
		Rating	***1***	***2***	***3***	***5***	***8***	***10***	***15***	***20***
4	Condition of discontinuities (see Table C)		Soft gouge > 5 mm thick or separation > 5 mm, continuous	Slickensided surfaces or gouge < 5 mm thick or separation 1 - 5 mm, continuous	Slightly rough surfaces, separation < 1 mm, highly weathered walls	Slightly rough surfaces, separation < 1 mm, slightly weathered walls	Very rough surfaces, not continuous, no separation, fresh walls			
		Rating	***0***	***10***	***20***	***25***	***30***			
5	Ground water	Inflow per 10 m of tunnel length (l/m)	> 125	25 - 125	10 - 25	< 10	None			
		(Joint water pressure) / (major principal stress σ)	> 0,5	0,2 - 0,5	0,1 - 0,2	< 0,1	0			
		General conditions	Flowing	Dripping	Wet	Dump	Dry			
		Rating	***0***	***4***	***7***	***10***	***15***			

Table B: Rating adjustment for discontinuities' orientation

Parameter	Range of values						
Strike of discontinuity	–	Perpendicular to tunnel axis				Parallel to tunnel axis	
Dip of discontinuity (°)	0 - 20	20 - 45	45 - 90	20 - 45	45 - 90	20 - 45	45 - 90
Tunnelling drive direction	N/A	Drive against dip		Drive with dip		N/A	
Rating [2]	*Fair*	*Unfav.*	*Fair*	*Fav.*	*Very fav.*	*Fair*	*Very fav.*
	-5	***-10***	***-5***	***-2***	***0***	***-5***	***0***

Table C: Guidelines for classification of discontinuitites' conditions [3]

Parameter	Range of values				
Persistance (m)	< 1	1 - 3	3 - 10	10 - 20	> 20
Rating	***6***	***4***	***2***	***1***	***0***
Aperture (mm)	None	< 0,1	0,1 - 1,0	1 - 5	> 5
Rating	***6***	***5***	***4***	***1***	***0***
Roughness	Very rough	Rough	Slightly rough	Smooth	Slickensided
Rating	***6***	***5***	***3***	***1***	***0***
Infilling	None	Hard < 5mm	Hard > 5mm	Soft < 5mm	Soft > 5mm
Rating	***6***	***4***	***2***	***2***	***0***
Weathering of discontinuity walls	Fresh	Slighty weathered	Moderately weathered	Highly weathered	Completely weathered
Rating	***6***	***5***	***3***	***1***	***0***

Table D: Rock classes determined from total ratings and their meaning

Parameter	Range of values				
Total rating	< 21	21 - 40	41 - 60	61 - 80	81 - 100
Class	V	IV	III	II	I
Description	Very poor rock	Poor rock	Fair rock	Good rock	Very good rock
Average stand-up time	30 min for 1 m spam	10 hr for 2,5 m spam	1 week for 5 m spam	1 yr for 10 m spam	20 yr for 15 m spam
Cohesion of rock mass (kPa)	< 100	100 - 200	200 - 300	300 - 400	> 400
Friction angle of rock mass (°)	< 15	15 - 25	25 - 35	35 - 45	> 45

NOTE 1 Based on "*Rock Mass Rating (RMR)* " system (Bieniawski, 1979). Modifications of rows 2 and 3 of Table A have been proposed by D.B. Hawkings, consultant of JV *Olympic Metro Construction* , and accepted by AM.

NOTE 2 For tunnels and mines, modified after Wickam et al. (1972).

NOTE 3 Some conditions are mutually exclusive. For example, if infilling is present, the roughness of the surface will be overshadowed by the inluence of the infilling material. In such cases use Table A.4 directly.

15 APPENDIX D: Borehole log (sample)

16 APPENDIX E: Data in digital format

Contractor provides the GI data of the Contract in AGS files in accordance with the AGS format (Association of Geotechnical and Geoenvironmental Specialists) (Version 4.0.4 February 2017 or later after AM's approval). Details of the format can be found at http://www.ags.org.uk. The proprietary structure of the AGS shall be provided by AM.

Contractor uses approved software for the production of AGS files, whose output shall fully satisfy the specifications of the AGS standard and of the proprietary structure. The Contractor transmits the data in a digital form via email, on a CD/DVD and/or via an FTP server.

Prior to the start of work, Contractor shall submit to AM a dummy set of data in AGS format. This dummy set of data shall contain data for all fields for which records are expected to be taken. The Contractor shall submit to AM updated AGS file as the works progress, which shall correspond to the submitted printed files. The Contractor shall produce two identical copies of each file. The first copy shall remain the property of the Contractor and shall be kept until the expiry of the contract. The second copy shall be delivered to AM.

Digital files not in AGS format (.pdf, .dwg, .doc, .xls, etc.) are submitted as attachments to the associated AGS file, fully correlated and referred to in the FILE Table of the same file (AGS). All attached files shall be saved in a folder named "FILE". The AGS file and the FILE folder with the attached files shall be zipped in a file bearing the same name as the name of the AGS file.

All digital transmissions, as well as other agreed transmission media, are securely labelled and clearly marked in accordance with the following standardized list of information (the respective field shown in parenthesis):

- AGS data
- Project's Title: _ (PROJ_ID).
- Transmittal Unique Number: _ (TRAN_ISNO)
- Recipient: ATTIKO METRO (TRAN_RECV)
- File generation data: DD/MM/YYYY (TRAN_DATE)
- Project Contractor: _ (TRAN_PROD)
- AGS Version: 4.0.4 (TRAN_AGS)

In addition, each transmittal shall be accompanied by a list with the following details for the ZIP file, the AGS file and the attached files:

- File name, including the extension,
- File creation data,
- File creation time,
- File size in bytes,
- A general description of the data contained in each file.

.

17 APPENDIX F: Codification of points of investigation and measurements

The purpose of this appendix is to provide a unified system for the codification of the ground investigation points (boreholes, trial pits, etc.) or measurements (ground water level measurements, etc.) and to render possible the identification of their details (such as location, type, etc.) by means of a code designation.

All points of investigation shall be designated by a unique code. Whenever there are earlier boreholes or trial pits executed by AM, then AM shall provide to the Contractor their pertinent codes, in order to avoid repetition of already assigned codes.

The code designation does not serve as a substitute for the correlation of the investigation point with geographical coordinates.

The total number of characters in a code shall be seven (7). The three first characters designate the location and type of the investigation or measurement point, while the last four characters are used as the sequence number. All shall be Latin characters (not the numbers).

More specifically, the first three characters are assigned with the following values:

1st character: it refers to the Thessaloniki Metro and is assigned with character **“T”**.

2nd character: it refers to the section (or extension) of Thessaloniki Metro and to the Metro extension to MACEDONIA Airport and is assigned with character **“A”**.

3rd character: it defines the type of the investigation point or of the measurement instrument and the assigned values are in accordance with Table 17.1.

Table 17.1 — Values assigned to the fifth character of the code of the investigation point

Value (Latin character)	Location of the investigation or measurement point
P	Sampling borehole, with piezometer
H	Sampling borehole, without piezometer
Z	Non sampling borehole, with piezometer
R	Pressuremeter borehole
C	Cone Penetration Test (CPT) borehole
Y	Trial pit
O	Pumping well / Well

18 APPENDIX G: Soil Classification according to Hellenic Soil Classification System

18.1 Introduction – Scope

This appendix describes the procedure for classifying the soils into groups of soils, in the framework of the geotechnical investigations and tests. The soils shall be classified on the basis of the Hellenic Soil Classification System, HSCS. This system was developed in order to cover the need for the application of a soil classification system in the framework of geotechnical investigations and tests carried out in Greece, which would be compliant with Eurocode 7 (ELOT EN 1997). This classification system was initially presented during the 7th Pan Hellenic Conference on Geotechnical Engineering of 2014 (Boronkay et. al., 2014). The first 2014 edition has been modified in this document for harmonization with ELOT EN ISO 14688-1:2017 and ELOT EN ISO 14666-2:2017.

NOTE All classification principles specified in ELOT EN ISO 14688-2:2017 have been taken into account with the following exceptions:

- In HSCS, in terms of fines, the percentage of 35% is used as distinction limit between fine and coarse soils contrary to the percentage of 50% proposed in Table 1 of ELOT EN ISO 14688-2:2017.
- In HSCS the field "CIL-SiL" is not used in the proposed fines plasticity chart as per ELOT EN ISO 14688-2:2017 (compare Figure 1 in ELOT EN ISO 14688-2:2017 with Figure 18.3 of the document).

18.2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ELOT EN 1997-1, *Eurocode 7: Geotechnical design – Part 1: General rules*

ELOT EN 1997-1, *Eurocode 7: Geotechnical design – Part 2: Ground investigation and testing*

ELOT EN ISO 14688-1, *Geotechnical investigation and testing – Identification and classification of soil – Part 1: Identification and description*

ELOT EN ISO 14688-2, *Geotechnical investigation and testing – Identification and classification of soil – Part 2: Principles for a classification*

ELOT EN ISO 14689, *Geotechnical investigation and testing – Identification, description and classification of rock*

ELOT EN ISO 17892-4, *Geotechnical investigation and testing – Laboratory tests on soil – Part 4: Determination of particle size distribution*

ELOT EN ISO 17892-12, *Geotechnical investigation and testing – Laboratory testing of soil – Part 12: Determination of liquid and plastic limits*

ELOT EN ISO 22475-1, *Geotechnical investigation and testing - Sampling methods and groundwater measurements - Part 1: Technical principles for execution*

18.3 Terms and definitions

For the purpose of this document, the following terms and definitions deriving from parts 1 and 2 of ELOT EN ISO 14688 are valid.

18.3.1 carbonate soil

soil containing a percentage of calcium carbonate > 1% (for more information, see para. 5.3 of ELOT EN ISO 14688-1).

18.3.2 anthropogenic soil

soil placed by human activity which can be divided into those composed of reworked natural soils and/or those composed of synthetic materials

NOTE Anthropogenic soil that can be further divided into *fill*, when deposit is placed with engineering control, or into *made ground* or *reconstituted ground*, when the deposit is placed without engineering control.

18.3.3 loess

windblown (aeolian) sediment (for more information, see para. 5.6 of ELOT EN ISO 14688-1)

18.3.4 activity index

$\boldsymbol{I_A}$

$$I_A = I_P / CF$$

the ratio of the plasticity index I_P to the per weight percentage % of the clay fraction in the soil *CF*

NOTE The activity index may provide an indication on the colloidal characteristics of the clay fraction and mainly concerns the type and the percentage of clay minerals and the organic colloids in the soil, as well as the existence of electrolytes in the water inside the soil pores.

NOTE The following terms can be used in relation to the activity of the soil: if $I_A \geq 1{,}25$ the soil is characterized as *active*, while when $0.75 < I_A < 1{,}25$ the soil is characterized as *normal* and when $I_A \leq 0{,}75$ as *inactive*.

18.3.5 plasticity index

$\boldsymbol{I_P}$

$$I_P = w_L - w_P$$

the difference between the liquid limit and the plasticity limit of fine grained soil

NOTE Soil whose plasticity limit is equal to zero or whose plasticity limit cannot be determined is termed non-plastic.

18.3.6 consistency index

$\boldsymbol{I_C}$

$$I_C = (w_L - w) / I_P$$

the difference between the liquid limit and the water content expressed as a percentage of the plasticity index

18.3.7 soil

aggregate of minerals and/or organic materials, which can be disaggregated by hand in water

NOTE The term also applies to made-ground materials exhibiting similar behaviour which however have been reworked and placed again or which are anthropogenic, e.g. backfill, crushed rock, mined materials etc.

NOTE Soil produced from weathered/ altered rocks presenting rock structures and/or tissues whose strength is lower than the strength of the rocks.

18.3.8 volcanic soil

unconsolidated pyroclastic sediment produced and formed by explosive volcanic eruption (for more information, see para. 5.5 of ELOT EN ISO 14688-1).

EXAMPLES *bombs, blocks, lapilli, volcanic ash* (see also para. 6.2.1 of ELOT EN ISO 14688-1)

18.3.9 sulfide soil

soil with high content of iron sulfide (for more information, see para. 5.4 of ELOT EN ISO 14688-1)

18.3.10 particle size distribution or grading
measure of the particle sizes of a soil and their distribution

18.3.11 particle size fraction or size fraction
portion of soil defined by a range of particle sizes
The names of the particle size fractions, their symbols and the range of their size are shown in Table 18.1 (see also Table 1 of ELOT EN ISO 14688-1).

Table 18.1 — Particle sizes and symbols of particle size fractions

Categories of particle size fractions	Particle size fractions	Symbols	Range of particle sizes (mm) [1]
Very coarse fractions	large boulder	lBo / lbo	> 630
	boulder	Bo / bo	> 200 and ≤ 630
	cobble	Co / co	> 63 and ≤ 200
Coarse fractions	gravel	Gr / gr	> 2 and ≤ 63
	coarse gravel	cGr / cgr	> 20 and ≤ 63
	medium gravel	mGr / mgr	> 6,3 and ≤ 20
	fine gravel	fGr / fgr	> 2 and ≤ 6,3
	sand	Sa / sa	> 0,063 and ≤ 2
	coarse sand	cSa / csa	> 0,63 and ≤ 2
	medium sand	mSa / msa	> 0,2 and ≤ 0,63
	fine sand	fSa / fsa	> 0,063 and ≤ 0,2
Fine fractions	silt	Si / si	> 0,002 and ≤ 0,063
	coarse silt	cSi / csi	> 0,02 and ≤ 0,063
	medium silt	mSi / msi	> 0,0063 and ≤ 0,02
	fine silt	fSi / fsi	> 0,002 and ≤ 0,0063
	clay	Cl / cl	≤ 0,002

NOTE 1 Particle size ranges for silt and clay are given only as a reference for the particle size of "silt particles" and "clay particles" and not for "silt" and "clay" as fine fractions

18.3.12 fines
the total of the soil fine fraction – namely the soil fraction passing from the 0.063 mm sieve – which can be classified as silt or clay

18.3.13 soil group
soils of similar composition and geotechnical properties

18.3.14 organic soil
soil containing a high proportion of plant and/or animal organic materials and the conversion products of those materials.

NOTE Organic soil presents very low density and, usually, a great percentage of humidity.

18.3.15 plastic limit
w_P
the water content where fine soil passes from the plastic to semi-consolidated state, as defined by the plastic limit determination test

18.3.16 liquid limit
w_L
the water content where fine soil passes from the liquid to the plastic sate, as defined by the liquid limit determination test

18.3.17 mineral soil
soil composed largely or entirely of inorganic constituents

18.3.18 water content
w
mass of water which can be removed from the soil, usually by drying, expressed as a percentage of the dry mass

18.3.19 coefficient or curvature
$\boldsymbol{C_C}$

$$C_C = (D_{30})^2/(D_{10} x D_{60})$$

where D_{60}, D_{30} and D_{10} are the particle diameters corresponding to 60 %, 30 % and 10 % finer on the cumulative particle size distribution curve, respectively

18.3.20 uniformity coefficient
$\boldsymbol{C_U}$

$$C_U = D_{60}/D_{10}$$

where D_{60} and D_{10} are the particle diameters corresponding to 60 % and 10 % finer on the cumulative particle size distribution curve, respectively

NOTE The particle size D_{10} is stated in the bibliography as active size (e.g. Koukis, G. CH. & Sampatakakis, N.S. (2002): *Technical Geology*, p. 516, Papasotiriou Publications, Athens, Greece, ISBN 978-960-7530-009-7).

18.3.21 classification of soil
integration of a soil to a soil group on the basis of characteristics and criteria related to the soil's behaviour and formation

18.3.22 till
multi-graded, not bedded sediment of glacigenic origin (for more information, see para. 5.7 of ELOT EN ISO 14688-1)

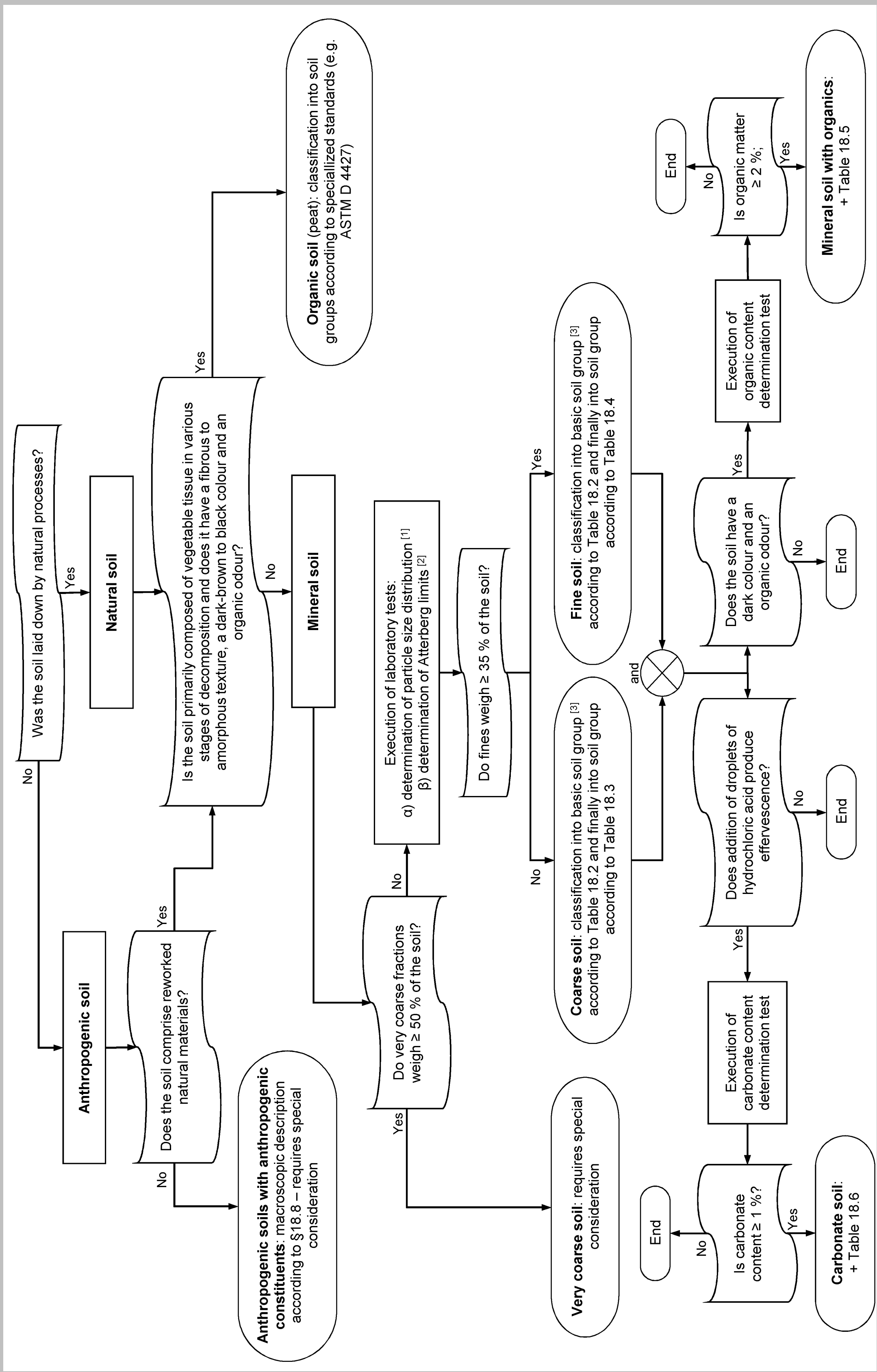
18.4 Summary

Based on the flowchart in Figure 18.1, the HSCS establishes three categories of soils, namely: coarse, fine and organic soils. These three categories are further divided into seventeen basic soil groups: eight basic groups of coarse soils, eight groups of fine soils (Table 18.2) and one basic group of organic soils (peat).

In detail, based on the macroscopic characteristics of the soils and further to the execution of specific laboratory tests, soils are assigned with a symbol and a name based on the soil group into which they have been classified in line with Tables 18.3 (groups of coarse soils) and 18.4 (groups of fine soils) and additionally in line with Tables 18.5 (mineral soils with organics) and 18.6 (carbonate soils). Special attention must be given when classifying anthropogenic soils with anthropogenic components, very coarse soils and organic soils.

18.5 Soil classification principles and application field

Figure 18.1 — HSCS soil classification system / Flowchart



NOTE 1 Regards the fraction passing the 63 mm sieve and retained on the 0,063 mm sieve. From sieve analysis, percentages of gravel, sand and fines are defined. In case that the fines are ≤ 10 %, the uniformity coefficient CU is defined, whereas in the case that the fines are > 10 % to < 15 %, only the particle size D_{60} is defined.

NOTE 2 Regards soils with fines ≥ 5 %. The liquid limit w_L and the plastic limit w_P are defined from which the plasticity index I_P is determined. Afterwards, the point $[w_L, I_P]$ is projected to diagram of Figure 18.3.

NOTE 3 The classification into a basic soil group represents an intermediate stage of soil classification, the scope of which is to identify soil beds more easily and to correlate them at the evaluation of geotechnical investigation results. This intermediate soil classification into basic soil groups is not reported since the name of the basic soil group is contained in the name of the soil group (letters in capitals).

Before proceeding with the classification of the soil, the soil shall be identified and macroscopically described in line with ELOT EN ISO 14688-1, while soil characteristics and the soil’s genetic origin shall be identified.

As regards its origin, soils are distinguished into *natural* and *anthropogenic*. Natural soils are further distinguished into *mineral soils* –including the *mineral soils with organics*, *volcanic soils*, *sulfide soils*, *carbonate soils*, *tills* and *loess*– and *organic soils*.

The HSCS is applicable to usual natural soils, as well as to anthropogenic soils of a similar composition encountered in Greece. Nevertheless, generally, it can be applied in any other geographical location.

The soils are classified into soil groups depending on their composition, irrespective of their water content or compactness, taking into account the particle size distribution, fine plasticity, the organics’ content, calcium carbonate content and the origin of the deposit.

Mineral soils are further divided based on their particle size distribution into *very coarse soils* (very coarse fractions ≥ 50 %), *coarse soils* (fines < 35 %) and *fine soils* (fines ≥ 35 %). The classification of the soil ends up in attributing a name and a symbol to the soil.

The procedure related to the identification and macroscopic description of the soil together with the classification procedure can be used for the purpose of describing the soil while these procedures contribute to the evaluation of its significant characteristics, so that they are used in geotechnical engineering. HSCS is applied on all soils with the following exceptions / special cases:

- The classification of the anthropogenic soils that include anthropogenic materials, requires a special treatment, in line with the stipulations of para. 18.8.
- Very coarse soils (> 50 % of the soil consists of very coarse fractions) require a special treatment.
- The classification of organic soils shall be made on the basis of other specialised standards (see para. 18.9).

18.6 Equipment

In addition to the devices required for soil sampling, preparation of the soil sample and execution of the specified laboratory tests, a chart with the particle size distribution curve similar to the one shown in Figure 18.2 and a plasticity chart similar to the chart shown in Figure 18.3 are required.

18.7 Sampling

Sampling is executed based on ELOT EN ISO 22475-1 (para. 6.6). Soil samples of quality classes 1 to 4 are required (see para. 3.4.1 of Eurocode 7 (ELOT EN 1997-2) and para. 6.2 of ELOT EN ISO 22475-1)

18.8 Classification of anthropogenic soils

Any soil which has not been placed by natural process shall be classified as anthropogenic soil.

If the anthropogenic soil includes only reworked natural components, it shall be classified in line with the provisions applicable for natural soil.

If anthropogenic soil also includes anthropogenic materials at a significant percentage, the macroscopic description of the soil shall include detailed recording of the following characteristics of these anthropogenic components (para. 6.2.4 of ELOT EN ISO 14688-1), namely:

- Origin of material
- Presence of large objects, e.g. concrete, masonry, ceramics, metallic items, etc.
- Presence of voids or collapsible hollow objects
- Chemical waste and dangerous or hazardous substances
- Organic matter with a note on the degree of decomposition
- Odorous smell
- Striking colour tints
- Any dates readable on buried papers etc
- Signs of underground heat or combustion (e.g. smoke emerging from borehole)
- Structure, variability and method of placement.

The classification of the anthropogenic soils, in case these involve anthropogenic materials, requires special handling, depending on their characteristics.

18.9 Classification of organic soils

For organic soils, the sole basic group is *peat* (symbol: Pt). Peat is recognized from its macroscopic characteristics: it is composed of plant residues of various degrees of decomposition, it has texture ranging from fibrous to amorphous, dark brown to black colour and organic odour.

In order to classify peat in soil groups, it is recommended to use specialized standards, (e.g. ASTM D 4427 or other equivalent standard).

NOTE If standard ASTM D 4427 is applied, the terminology for peat classification is provided in paragraph 18.13.

18.10 Classification of mineral soils

18.10.1 Classification of very coarse soils

If during the macroscopic description it is ascertained that very coarse fractions are ≥ 50 % the soil shall be characterized as very coarse while its classification requires special handling. Otherwise, the procedure described in paragraphs 18.10.2 to 18.10.6 shall apply.

18.10.2 Preparation for classification

18.10.2.1 Macroscopic description and identification of soil

Before classifying the soil, it is required to proceed with the macroscopic description and identification of the soil in line with paragraph 13.3. The macroscopic description shall identify, in terms of quality, very coarse fractions –cobbles, boulders and large boulders– whether the soil is natural or anthropogenic, mineral or organic, mineral with organics or carbonate soil (for the examined characteristics, see Figure 18.1).

18.10.2.2 Necessary laboratory tests

After the macroscopic description, the following laboratory tests are executed:

a) In all soils the *particle size analysis with sieves* must be performed for determining the soil fraction passing through a 63 mm sieve, in line with standard ELOT EN ISO 17892-4, using as a minimum the following series of standards on sieves (as per ISO 3310-1 and ISO 3310-2):.
   - 63 mm
   - 20 mm
   - 6,3 mm
   - 2,0 mm
   - 0,63 mm
   - 0,20 mm

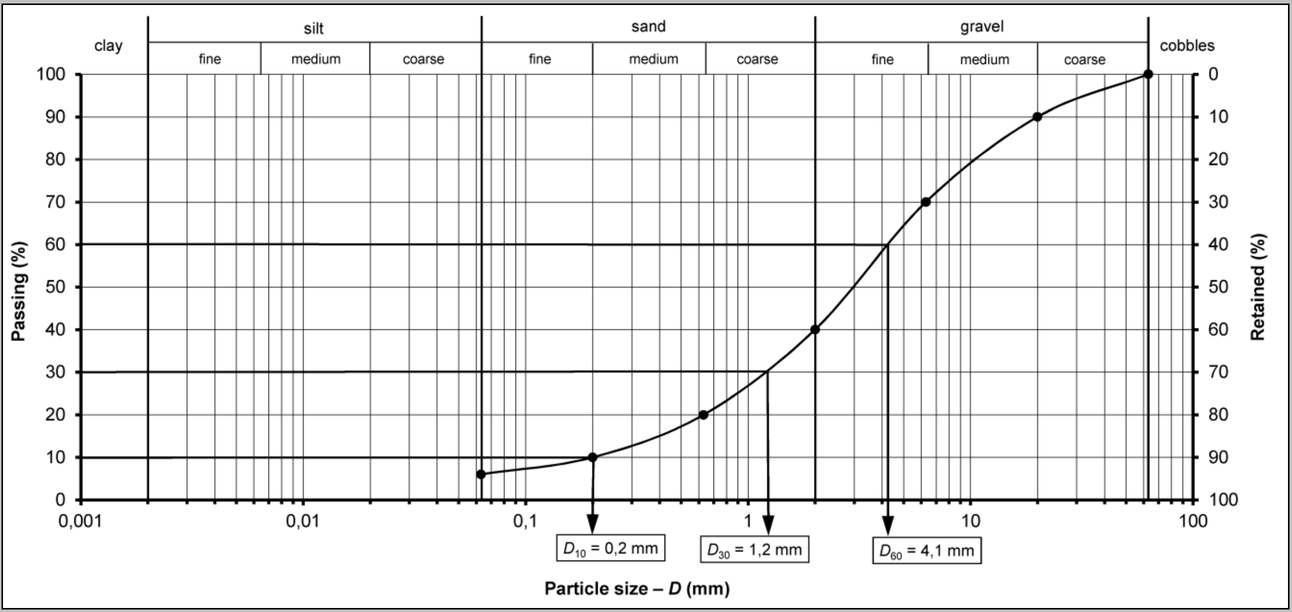
– 0,063 mm

NOTE The fractions retained by the 63 mm sieve are not considered in the soil sample's particle size analysis and their participation percentages do not participate in the particle size distribution curve.

NOTE Even though the testing procedure for identifying the particle size grading may require an analysis using a sedimentation process, testing for identifying the particle size grading through a sedimentation process is not necessary for the classification of the soil

The results of the particle size analysis shall be shown on a diagram similar to the semi algorithmic diagram of Figure 18.2 in the form of a particle size distribution curve. From the particle size distribution curve the proportions of the basic particle size fractions of the soil shall be determined, namely: gravel, sand and fines.

Figure 18.2 — Particle size distribution curve diagram – Particle size distribution curve for coarse soil with fines < 10 %



The percentage of the very coarse fractions (fraction retained by the 63mm sieve) is recorded as an additional element. The maximum particle size of the soil D_{max} is also measured and recorded.

b) In case of soils with fines ≥ 5 %, in addition to the requirements of clause 18.10.2.2(a), the execution of the *test for the determination of the liquid limit* (w_L) and the *test for the determination of the plastic limit* (w_P) *of fines* is required, in line with ELOT EN ISO 17892-12. The plasticity index (I_P) is calculated from the liquid limit and the plastic limit; then, point [w_L, I_P] is projected onto a plasticity chart similar to the one of Figure 18.3.

NOTE The tests for the determination of the liquid limit and the plasticity limit are executed on the soil fraction passing through a 0.425 mm or a 0.4 mm sieve.

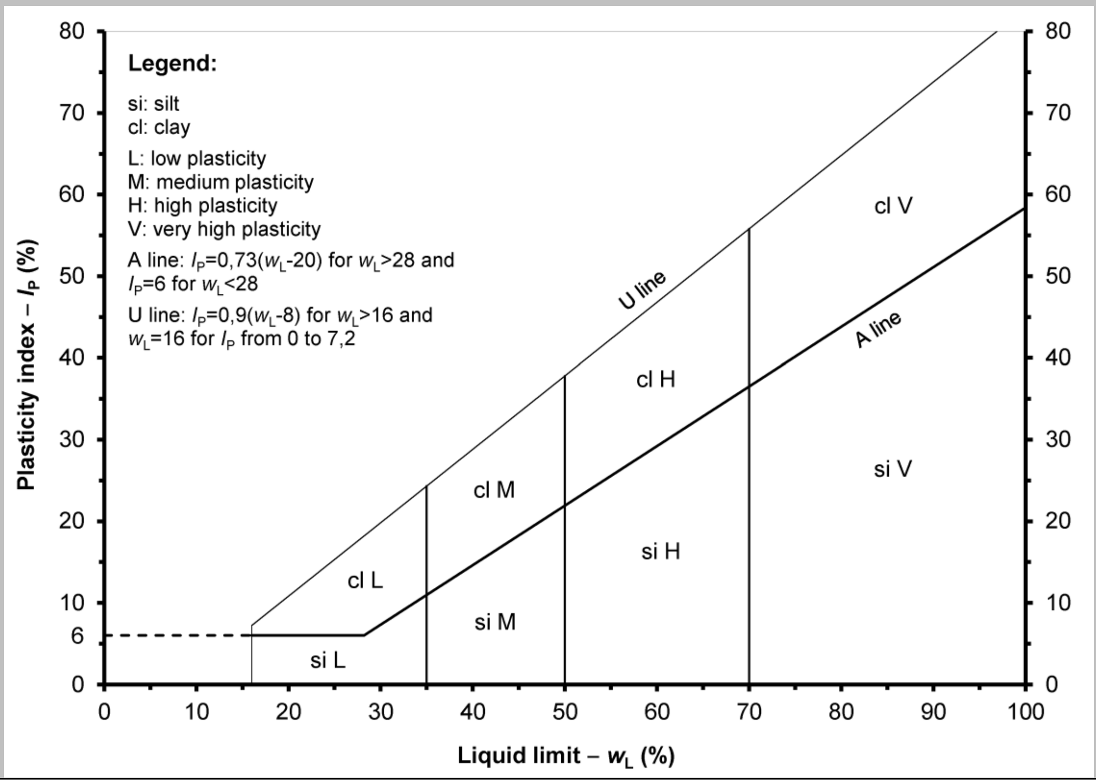
c) In case of soils with fines < 10 %, in addition to the requirements of clauses 18.10.2.2(a) and (b), it is necessary to proceed with the *determination of particle sizes* D_{60}, D_{30} and D_{10} (Figure 18.2).

d) In case of soils with fines ≥ 10 % and < 15 %, in addition to the requirements of clauses 18.10.2.2(a) and 18.10.2.2(b), it is necessary to proceed with the *determination of particle size* D_{60} (Figure 18.2).

NOTE The difference in determining particle sizes D_{60}, D_{30} and D_{10} in soils with fines < 10 % and in soils with fines ≥ 10 % and < 15 % derives from the fact that in the second case it is not possible to determine particle size D_{10} from the particle size distribution curve; thus, the relevant criterion for grading these coarse soils is modified (see 18.10.4).

Figure 18.3 — Plasticity chart of HSCS for the classification of fines (modified by ELOT EN ISO

14688-2, BS 5930 and ASTM D 2487)



NOTE The U line has been empirically determined to be the approximate "upper limit" for natural soils. It is a good check against erroneous data, and any test results that plot above or to the left of it should be verified.

e) In case of mineral soils with dark colour and odorous smell, in addition to the requirements of clauses 18.10.2.2(a) up to 18.10.2.2(d), the relevant tests for *the determination of the percentage of the organics* must be executed. In soils with a very small percentage of clay fraction and/or carbonates, the percentage of organics is usually determined from the loss at ignition, under controlled temperature. The other method of determination is the loss of mass during processing with hydrogen peroxide (H_2O_2). The percentage of organics is determined according to ASTM D 2974 or AASHTO T 194 or other equivalent standard.

f) If during the addition of drops of hydrochloric acid solution (10 % HCl), the mineral soil becomes effervescent (see Table 7 ELOT EN ISO 14688-1), in addition to the requirements of clauses 18.10.2.2(a) to 18.10.2.2(e), the *execution of the test for the determination of the percentage of calcium carbonate* in line with standard BS 1377-3 or other equivalent standard is required.

18.10.2.3 Classification of fines

Fines are classified in whole as clay or silt, depending on their plasticity and not their particle size distribution. The plasticity of the fines is determined by means of tests to determine the plastic limit (w_P) and the liquid limit (w_L), (clause 18.10.2.2(b) by projecting the point [w_L, $I_P = w_L - w_P$] onto the plasticity chart shown in Figure 18.3.

Depending on the field of the plasticity chart onto which the point [w_L, I_P] is projected, the fine fraction is classified as follows:

- If the point is projected above line A, fines are characterized as *clay*, while depending on the liquid limit of the clay, they are characterized as *low plasticity clay* (w_L < 35 %), *intermediate plasticity clay* (35 % < w_L ≤ 50 %), *high plasticity clay* (50 % < w_L ≤ 70 %) and *clay of very high plasticity* (w_L > 70 %).

- Similarly, if the point [w_L, I_P] is projected below line A, fines are characterised as silt, while depending on the liquid limit of the silt, they are characterized as *silt* (w_L < 35 %), *intermediate plasticity silt* (35 % < w_L ≤ 50 %), *high plasticity silt* (50 % < w_L ≤ 70 %) and *silt of very high plasticity* (w_L > 70 %).

NOTE The term “low plasticity silt” is not used since it is a redundancy to characterize the silt as “low plasticity.

18.10.3 Initial classification into basic soil groups

Soils with fines < 35 % are classified as coarse soil, while soils with fines ≥ 35 % are classified as fine soil. Coarse and fine soils are classified in the basic groups of soils presented in Table 18.2 based on the criteria of the percentage of gravels, sand and fines and based on the classification of the fines.

Similarly, soils are classified into groups of soils in line with paragraphs 18.10.4, 18.10.5 and 18.10.6.

NOTE The classification into a basic soil group constitutes an intermediate stage which aims at ensuring a simpler distinction of the soil layers and their correlation during the stage of the evaluation of the results of the geotechnical investigation and is not recorded, since the name of the basic group of soils is included in the name of the soil group.

Table 18.2 — Basic groups of mineral soils

	Classification criteria of mineral soils					**Basic groups of mineral soils**	
	Percentage of fines	**Percentages of coarse fractions**		**Classification of fines**		**Symbol**	**Name [1]**
Coarse soils	< 15 %	gr > sa	sa < 20 %	—		**Gr**	GRAVEL
			sa ≥ 20 %			**saGr**	SANDY GRAVEL
		sa ≥ gr	gr ≥ 20 %			**grSa**	GRAVELLY SAND
			gr < 20 %			**Sa**	SANDY GRAVEL
	≥ 15 % and < 35 %	gr > sa		si		**siGr**	SILTY GRAVEL
				cl		**clGr**	CLAYEY GRAVEL
		sa ≥ gr		si		**siSa**	SILTY SAND
				cl		**clSa**	CLAYEY SAND
Fine soils	≥ 35 %	—		si	L	**SiL**	SILT
					M	**SiM**	MEDIUM PLASTICITY SILT
					H	**SiH**	HIGH PLASTICITY SILT
					V	**SiV**	VERY HIGH PLASTICITY SILT
				cl	L	**ClL**	LOW PLASTICITY CLAY
					M	**ClM**	MEDIUM PLASTICITY CLAY
					H	**ClH**	HIGH PLASTICITY CLAY
					V	**ClV**	VERY HIGH PLASTICITY CLAY

18.10.4 Classification of coarse soils

Coarse soils are classified based on the flow chart shown in Table 18.3.

If fines are < 15 %, the classification criteria also include, in addition to the percentage of gravel, sand and fines and the classification of fines, the soil grading criterion. If fines are ≤ 10 % and the uniformity coefficient C_U is ≥ 6, then the soil shall be characterised as *wide-graded soil,* while if C_U is < 6, the soil shall be characterised as *narrow-graded soil.* If fines are > 10 % and < 15 %, if particle size D_{60} is ≥ 0,378, then the soil shall be characterized as *wide-graded soil*, while if D_{60} < 0,378, the soil shall be characterized as *narrow-graded soil.*

If fines are ≥ 15 % and < 30 %, classification criteria include the percentages of gravel and sand and the classification of fines to silt or clay.

Table 18.3 — Coarse soil groups – Flow chart

				Symbol			Soil group name [2]
fines <15%	gr>sa	C_U≥6 or D_{60}≥0,378 [1]	sa<20%	Gr-w	fines <5%		Wide-graded GRAVEL
					5%≤ fines <15%	fines = si	Wide-graded slightly silty GRAVEL
						fines = cl	Wide-graded slightly clayey GRAVEL
			sa≥20%	saGr-w	fines <5%		Wide-graded SANDY GRAVEL
					5%≤ fines <15%	fines = si	Wide-graded slightly silty SANDY GRAVEL
						fines = cl	Wide-graded slightly clayey SANDY GRAVEL
		C_U<6 or D_{60}<0,378 [1]	sa<20%	Gr-n	fines <5%		Narrow-graded GRAVEL
					5%≤ fines <15%	fines = si	Narrow-graded slightly silty GRAVEL
						fines = cl	Narrow-graded slightly clayey GRAVEL
			sa≥20%	saGr-n	fines <5%		Narrow-graded SANDY GRAVEL
					5%≤ fines <15%	fines = si	Narrow-graded slightly silty SANDY GRAVEL
						fines = cl	Narrow-graded slightly clayey SANDY GRAVEL
	sa≥gr	C_U≥6 or D_{60}≥0,378 [1]	gr≥20%	grSa-w	fines <5%		Wide-graded GRAVELLY SAND
					5%≤ fines <15%	fines = si	Wide-graded slightly silty GRAVELLY SAND
						fines = cl	Wide-graded slightly clayey GRAVELLY SAND
			gr<20%	Sa-w	fines <5%		Wide-graded SAND
					5%≤ fines <15%	fines = si	Wide-graded slightly silty SAND
						fines = cl	Wide-graded slightly clayey SAND
		C_U<6 or D_{60}<0,378 [1]	gr≥20%	grSa-n	fines <5%		Narrow-graded GRAVELLY SAND
					5%≤ fines <15%	fines = si	Narrow-graded slightly silty GRAVELLY SAND
						fines = cl	Narrow-graded slightly clayey GRAVELLY SAND
			gr<20%	Sa-n	fines <5%		Narrow-graded SAND
					5%≤ fines <15%	fines = si	Narrow-graded slightly silty SAND
						fines = cl	Narrow-graded slightly clayey SAND
15%≤ fines <35%	gr>sa		fines = si	siGr		sa≥20%	Sandy SILTY GRAVEL
						sa<20%	SILTY GRAVEL
			fines = cl	clGr		sa≥20%	Sandy CLAYEY GRAVEL
						sa<20%	CLAYEY GRAVEL
	sa≥gr		fines = si	siSa		gr≥20%	Gravelly SILTY SAND
						gr<20%	SILTY SAND
			fines = cl	clSa		gr≥20%	Gravelly CLAYEY SAND
						gr<20%	CLAYEY SAND

NOTE 1 In case that fines are ≤ 10 %, the criterion of the coefficient of curvature C_U is applied. Relatively, in the case that fines are > 10 % to < 15 %, the criterion of the particle size D_{60} is applied.

NOTE 2 If the soil sample contains very coarse fractions, add the term "with cobbles" or "with boulders" or "with large boulders" or the appropriate combination of very coarse fractions to group name. The symbol of the soil group does not change.

18.10.5 Fine soils classification

Fine soils are classified based on the flow chart of Table 4. Classification criteria include classification of fines into silt or clay, their plasticity (low L, intermediate M, high H or very high V) and the percentages of gravel and sand.

Table 18.4 — Fine soils groups – Flow chart

Symbol						Soil group name [1]
fines ≥ 35 %	fines = si	plasticity = L → SiL	gr≥20%	sa≥20%	gr>sa	Sandy gravelly SILT
					sa≥gr	Gravelly sandy SILT
				sa<20%		Gravelly SILT
			gr<20%	sa≥20%		Sandy SILT
				sa<20%		SILT
		plasticity = M → SiM	gr≥20%	sa≥20%	gr>sa	Sandy gravelly MEDIUM PLASTICITY SILT
					sa≥gr	Gravelly sandy MEDIUM PLASTICITY SILT
				sa<20%		Gravelly MEDIUM PLASTICITY SILT
			gr<20%	sa≥20%		Sandy MEDIUM PLASTICITY SILT
				sa<20%		MEDIUM PLASTICITY SILT
		plasticity = H → SiH	gr≥20%	sa≥20%	gr>sa	Sandy gravelly HIGH PLASTICITY SILT
					sa≥gr	Gravelly sandy HIGH PLASTICITY SILT
				sa<20%		Gravelly HIGH PLASTICITY SILT
			gr<20%	sa≥20%		Sandy HIGH PLASTICITY SILT
				sa<20%		HIGH PLASTICITY SILT
		plasticity = V → SiV	gr≥20%	sa≥20%	gr>sa	Sandy gravelly VERY HIGH PLASTICITY SILT
					sa≥gr	Gravelly sandy VERY HIGH PLASTICITY SILT
				sa<20%		Gravelly VERY HIGH PLASTICITY SILT
			gr<20%	sa≥20%		Sandy VERY HIGH PLASTICITY SILT
				sa<20%		VERY HIGH PLASTICITY SILT
	fines = cl	plasticity = L → ClL	gr≥20%	sa≥20%	gr>sa	Sandy gravelly LOW PLASTICITY CLAY
					sa≥gr	Gravelly sandy LOW PLASTICITY CLAY
				sa<20%		Gravelly LOW PLASTICITY CLAY
			gr<20%	sa≥20%		Sandy LOW PLASTICITY CLAY
				sa<20%		LOW PLASTICITY CLAY
		plasticity = M → ClM	gr≥20%	sa≥20%	gr>sa	Sandy gravelly MEDIUM PLASTICITY CLAY
					sa≥gr	Gravelly sandy MEDIUM PLASTICITY CLAY
				sa<20%		Gravelly MEDIUM PLASTICITY CLAY
			gr<20%	sa≥20%		Sandy MEDIUM PLASTICITY CLAY
				sa<20%		MEDIUM PLASTICITY CLAY
		plasticity = H → ClH	gr≥20%	sa≥20%	gr>sa	Sandy gravelly HIGH PLASTICITY CLAY
					sa≥gr	Gravelly sandy HIGH PLASTICITY CLAY
				sa<20%		Gravelly HIGH PLASTICITY CLAY
			gr<20%	sa≥20%		Sandy HIGH PLASTICITY CLAY
				sa<20%		HIGH PLASTICITY CLAY
		plasticity = V → ClV	gr≥20%	sa≥20%	gr>sa	Sandy gravelly VERY HIGH PLASTICITY CLAY
					sa≥gr	Gravelly sandy VERY HIGH PLASTICITY CLAY
				sa<20%		Gravelly VERY HIGH PLASTICITY CLAY
			gr<20%	sa≥20%		Sandy VERY HIGH PLASTICITY CLAY
				sa<20%		VERY HIGH PLASTICITY CLAY

NOTE 1 If the soil sample contains very coarse fractions, add the term "with cobbles" or "with boulders" or "with large boulders" or the appropriate combination of very coarse fractions to group name. The symbol of the soil group does not change.

18.10.6 Classification of mineral soils with organics and calcareous soils

18.10.6.1 Classification of mineral soils with organics

Mineral soils with organics are classified into soil groups as follows: once the soil is classified into the relevant group of coarse or fine mineral soil and provided that the soil is dark coloured and has odorous smell, the percentage of the organics shall be examined: depending on the percentage of the organics and if the percentage is ≥ 2 %, the respective term shall be added to the end of the soil group name, while the symbol of the soil group shall be modified accordingly, in line with Table 18.5 (see also Table 3 of ELOT EN ISO 14688-2).

Table 18.5 — Additional terms and symbols used for groups of mineral soils with organics

Organic content of dry mass	Additional symbol	Terms to be added to the name of the soil group
≥ 2 % to < 6 %	(or)...	… low-organic
≥ 6 % to < 20 %	or…	… medium-organic
≥ 20 %	Or…	… high -organic

EXAMPLE sandy gravely MEDIUM PLASTICITY CLAY high-organic (or ClM)

18.10.6.2 Classification of carbonate soils

Similarly to mineral soils with organics, the classification of the carbonate soils is made taking into account the calcium carbonate percentage in soil as follows: once the soil is classified to the group of mineral soils and provided that there is soil effervescence once drops of hydrochloric acid solution (10 % HCl) are dripped to it, the percentage of calcium carbonate is examined. Depending on the calcium carbonate percentage and provided that the percentage is ≥ 1%, the respective adjective shall be added at the beginning of the soil group name in line with Table 18.6 (see also Table 4 of ELOT EN ISO 14688-2), while the symbol of the soil group is not modified.

Table 18.6 — Additional terms used for the groups of carbonate soils

Carbonate content	Terms to be added to the name of the soil group
< 1 %	–
≥ 1 % to < 5 %	slightly calcareous …
≥ 5 % to < 25 %	calcareous …
≥ 25 % to < 50 %	highly calcareous …
≥ 50 %	very highly calcareous …

EXAMPLE Highly carbonate sandy gravely HIGH PLASTICITY CLAY (ClH)

18.10.6.3 Classification of carbonate soils with organics

Mineral soils may be carbonate soils and may contain organics. In this case, both classification procedures shall apply, namely the procedure related to the classification of mineral soil with organics (para. 10.6.1) and the procedure related to the classification of carbonate soil (para. 10.6.2). Thus, with regard to the name of the soil, Tables 18.5 and 18.6 shall apply.

EXAMPLE carbonate CLAYEY SAND low-organic ((or)clSa)

18.10.7 Additional classification principles

Onsite conditions and/or geotechnical design requirements may lead to additional soil classification principles than the ones presented in para. 18.5. These may include on a per case basis the parameters of para. 5 of ELOT EN ISO 14688-2 or of Table 2, para. 4.3 of the same standard (figure showing the particle size distribution curve) which are not used in the HSCS.

18.11 Reporting

The data required for the classification of the soil samples shall be recorded in a data sheet and shall include the following info, as a minimum (see also Figure 18.4):

a) the details of the lab, the name and the signature of the certified laboratory employee who conducted the tests described in para. 18.10.2.2 and the classification date,
b) the project's data,
c) the details of the soil sample, i.e. the borehole code and the borehole coordinates X, Y, Z, as well as the sample code for samples obtained from sampling boreholes or borehole coordinates X, Y, Z and the sample code for samples obtained from natural exposure.

Figure 18.4 — HSCS data sheet

Classification of soil sample according to HSCS

Sample data				Company name:
Sample from natural exposure ☐			Coordinates of borehole or of natural exposure	Clinet's name:
Sample from borehole ☐				Project / Contract
Borehole:			X:	Name of certified laboratory personnel:
Sample depth:			Y:	Signature of certified laboratory personnel:
Sample No:			Z:	Date:

Particle size distribution (diagramm 1)

Sieve (mm)	Passing fraction (%)	Particle size (mm)	Passing fraction (%)	Coefficients of uniformity (C_U) and curvature (C_C)		**Classification of fines (diagramm 2)**		**Organic content (%)**	
63	100			D_{60} =		w_L =		organic matter	
20				D_{30} =		w_P =			
6,3				D_{10} =		I_P =			
2,0									
0,63				C_U =				**Carbonate content (%)**	
0,20				C_C =					
0,063									
Fraction retained on sieve 63 mm:								$CaCO_3$	
Maximum particle size (D_{max}):									

Basic fractions	Particle size distribution with sieving report:
	Particle size distribution with sedimntation report:
gravel (%) =	Determination of liquid limit and plastic limit reports:
sand (%) =	Determination of organics report / Type of test:
fines (%) =	Determination of carbonate content report:

Diagramm 1 – Particle size distribution curve

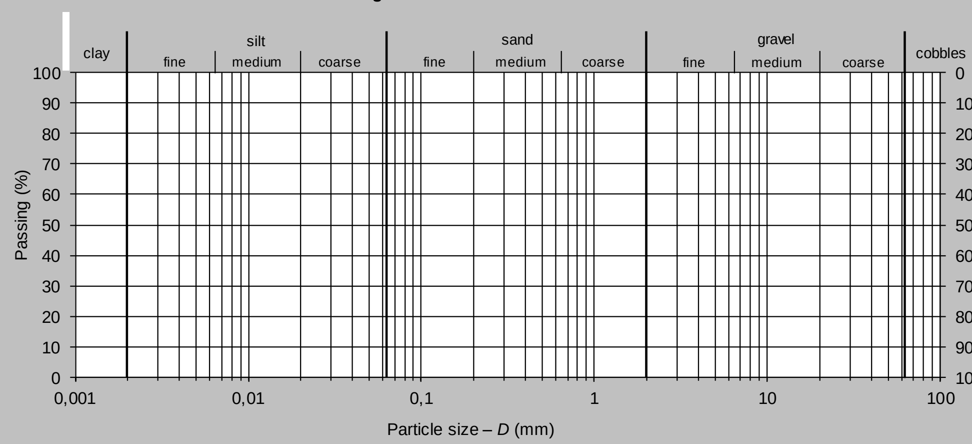
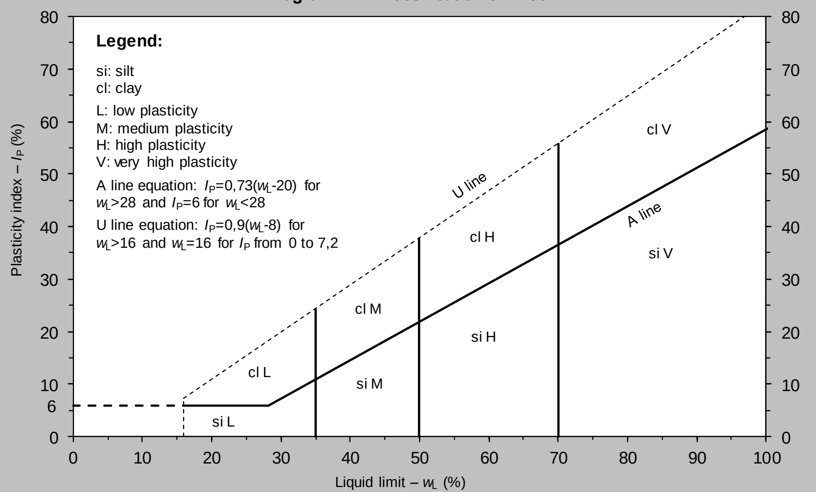


Diagramm 2 – Classification of fines



Classification according to HSCS	Soil symbol:
	Soil name:

d) the results (applicable each time) of:
   - the particle size analysis with sieves (percentage of particles passing through each sieve), including the percentages of gravels, sand and fines D_{60}, D_{30} and D_{10}, uniformity coefficient C_U, the curvature coefficient C_C and the percentage of very coarse fractions and of the maximum particle size D_{max} of the sample,
   - the hydrometer or pipette analysis for fines,
   - the determination of the liquid limit w_L, plastic limit w_P and plasticity index I_P,
   - the soil sample organics determination results,
   - the results of the tests for determining the calcium carbonate in the soil sample

e) references to the sheets with the results of the above tests executed for the classification of the soil sample,

f) the chart with the particle size distribution of the soil sample (particle size distribution curve),

g) the plasticity chart presenting the classification of the fine of the soil sample and

h) the symbol and name of the soil in line with HSCS classification.

18.12 Abbreviation symbols for soil classification per HSCS

In many instances, due to lack of space, an abbreviations system that specifies the name and symbol of the soil classification per HSCS can be of great use. Examples of such instances are borehole logs, databases, tables with records of geotechnical investigation records, etc.

These abbreviations do not substitute for the name and symbol of the soil classification per HSCS and the soil description, but may be used in supplementary presentations of data, when reference is made to the full description.

In this system of abbreviations the following symbols are used:

lbo = large boulders
bo = boulders
co = cobbles
gr = gravel
sa = sand
si = silt, silty, slightly silty
sil = (low plasticity) silt
sim = medium plasticity silt
sih = high plasticity silt
siv = very high plasticity silt
cl = clay, clayey, slightly clayey
cll = low plasticity clay
clm = medium plasticity clay
clh = high plasticity clay
clv = very high plasticity clay

w = wide graded
n = narrow graded
o1 = few organics
o2 = moderately organic
o3 = highly organic
c1 = slightly calcareous
c2 = calcareous
c3 = very calcareous
c4 = highly calcareous

The rules for soil abbreviations are as follows:

a) The soil symbol abbreviation –as shown in Tables 18.2 and 18.3– goes first, followed by a dot.

   NOTE The abbreviation for the additional symbol concerning the organics (Table 18.5) follows after the dot (see section (c)).

   The correspondence between the abbreviations and the soil symbols per HSCS is presented in Table 18.7.

Table 18.7 — Correspondence between the abbreviations and the soil symbols per HSCS

Soil Symbol	Abbreviation	Soil Symbol	Abbreviation

per HSCS	
Gr-w	grw.
Gr-n	grn.
saGr-w	grsaw.
saGr-n	grsan.
siGr	grsi.
clGr	grcl.
Sa-w	saw.
Sa-n	san.
grSa-w	sagrw.
grSa-n	sagrn.
siSa	sasi.
clSa	sacl.

per HSCS	
SiL	sil.
SiM	sim.
SiH	sih.
SiV	siv.
ClL	cll.
ClM	clm.
ClH	clh.
ClV	clv.

b) Next comes the abbreviation of the secondary fractions corresponding to the terms e.g. "slightly silty", "sandy", "sandy gravel", "with stones", "with boulders and stones". In case of two or more secondary fractions, the order of the fractions in the abbreviation corresponds to the rate of their presence in the soil (from the highest to the lowest).

c) The next is the abbreviation of the terms referring to the organics (in Table 18.5), and lastly the abbreviations of the terms referring to the calcium carbonate content.

Based on the above rules, here are some examples of abbreviations for certain soils in Table 18.8.

Table 18.8 — Soil abbreviations examples

Soil name and symbol per HSCS	Abbreviation
Calcareous, slightly silty, widely-graded SANDY GRAVEL with cobbles (saGr-w)	grsaw.sicoc2
Narrow-graded GRAVELY SAND with cobbles and boulders (grSa-n)	sagrn.cobo
Slightly silty GRAVELY SAND (grSa)	sagr.si
Slightly calcareous sandy CLAYEY GRAVELS (clGr)	grcl.sac1
CLAYEY SAND with few organics and cobbles ((or)clSa)	sacl.coo1
Very calcareous sandy gravely SILT (SiL)	sil.grsac3
Gravely sandy HIGH PLASTICITY CLAY moderately organic (orClH)	clh.sagro2
Very highly calcareous sandy VERY HIGH PLASTICITY CLAY high-organic (OrClV)	clv.sao3c4

18.13 Peat classification terminology as per ASTM D 4427

This appendix provides the terms in standard ASTM D 4427, if this standard is selected to classify peat.

Fibre content:

- *Fibric* (fibres > 67 %)
- *Hemic* (fibres 33 % – 67 %)
- *Sapric* (fibres < 33 %)

Ash content:

- *Low ash* (ash < 5 %)
- *Medium ash* (ash 5 % – 15 %)
- *High ash* (ash > 15 %)

pH-related terms (acidity):

- *Highly acidic* (pH < 4,5)
- *Moderately acidic* (pH 4,5 – 5,5)

- *Slightly acidic* (pH 5,5 – 7)
- *Basic* (pH > 7)

Absorbency:

- *Extremely absorbent* (absorbency 800% >1500%)
- *Highly absorbent* (absorbency > 1500 %)
- *Moderately absorbent* (absorbency 300 % – 800 %)
- *Slightly absorbent* (absorbency < 300 %)

The terms concerning the botanical composition remain in Latin.

Example of terms for the classification of peat according to standard ASTM D 4427:

Peat, fibre content 55 %, ash content 8 %, pH = 4,7, absorbency 1200 %, with 70 % of its fibres originating from *Sphagnum* and 20 % of the fibers from *Carex* is classified as follows:

Hemic, medium-ash, moderately acidic, highly absorbent *Carex-Sphagnum* peat (Pt).