Building feasibility study to the site 'Rouscht' in L-Bissen
(North Plateau: 'Bousbierg', 'Donkelsuecht')

Geotechnical building feasibility study

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Table of contents

Attachment directory

Annexe 1:	Location of the site Topographical map of the site Aerial view of the site
Annexe 2:	Management situation (plans POST, Creos, municipality)
Annexe 3:	Pedological map of the site Hydrological map of the site Geological maps (LUCIUS, SERVICE GEOLOGIQUE 1983) Geological section of the site Earthquake zone map
Annexe 4:	Topographical measurement
Annexe 5:	Result of the geoelectric mapping
Annexe 6:	Site plan of the drillings
Annexe 6.1:	Dry drillings R1 - R9
Annexe 6.2:	Density Estimation D1 – D15
Annexe 6.3:	Rotation holes F1 - F8: Drilling profile, drilling recorder, photos, MENARD tests, standpipe
Annexe 6.4:	Geological map according to drilling data Sectional Drawings AA`, BB`, CC`
Annexe 6.5:	Topsoil thickness map
Annexe 6.6:	Map of the groundwater situation
Annexe 6.7:	Standard hydro-geological profile
Annexe 7:	Geotechnical examination
Annexe 7.1:	Determination of the soil type
Annexe 7.2:	Shear tests
Annexe 7.3:	MENARD tests
Annexe 8:	Chemical analysis
Annexe 8.1:	Examination of topsoil samples
Annexe 8.2:	Calcium and sulphate analyses
Annexe 8.3:	Groundwater analysis
Annexe 9:	Geopotentials
Annexe 9.1:	Utilization structure according to geotechnical criteria 'Cut and Fill Option 267 mNN'

Part 1: Site characterization

1. Process, goal and procedure

In L-Bissen, on the northern part of the plateau "Rouscht", on a total area of 34.5 hectares, is planned the construction of buildings for commercial use. In the project description of the PM Group of 30-31/08/2016, the basic requirements for the planned preliminary investigations are described.

The current geotechnical construction feasibility study is divided into the following sections:

Part 1. Site characterization; **Topographical site survey**
Pedological and geological site survey
Groundwater situation

Part 2. Geotechnical examination: **Engineering geological characteristics**

Part 3. Environmental investigation: **Initial status of soil and groundwater**

Part 4. Presentation of geo-risks and geopotentials of the site

On 16 September 2016, Fugro Luxembourg Sàrl will present the relevant offer, which is commissioned by PM Group to Fugro Luxembourg Sàrl on 8 November 2017.

The field investigations will start on 13/11/2017 after submission of the line plans and after release of the properties for the investigations and will be completed on 01/02/2018. The results of the geotechnical and environmental laboratory tests will be transmitted by 05/03/2018.
Coordination with representatives of the PM Group on the interim results takes place on the

23/11/2017	Site visit
16/12/2017	First review of field data
25/01/2018	Site visit
05/03/2018	Provision of the field data and maps

2 Terrain situation and construction project

2.1 Location

The site with a total area of approx. 34.5 ha is centrally located in Luxembourg (Annexe 1). It is located approx. 20 km north of Luxembourg City, near the A7 motorway between Mersch and Ettelbrück.
The planning area includes the 'Buusbierg' and 'Donkelsuecht' areas in Bissen.

Administrative allocation:	Country:	Luxembourg
	Canton:	Mersch
	Municipality:	Bissen
	Section:	B Süd-Bissen

2.2 Climatic characteristics

The climatic characteristics (annual average) are given in relation to the nearest weather station in Ettelbruck and for the comparison of Dublin:

Climatic data	L-Ettelbruck	IRL-Dublin
Temperature	9.6	9.6
Precipitation	854	731
Humidity	78	83

2.3 Current terrain situation and historical documentation

At the time of the survey, the terrain is divided into the following area units (Annexe 1):

Forest area:	15.6%
Agricultural area:	49.6%
Green area:	34.1%
Traffic area:	< 1%
Development:	0%

The site is not registered in the register of contaminated sites (CASIPO) of the Environmental Administration of Luxembourg.

On the basis of historical topographical maps and aerial photographs, it can be stated that the industrial area bordering to the south was created between 2004 and 2007.
The topographic maps show no change in the structure of the entire area until 1907.
The topographical map from the year 1778 (first survey) shows a much higher proportion of forest on the total area, so it can be assumed that the area was forested at this time and was cleared and developed in the 19th century.

2.4 Surface Water (Annexe 3)

The site is surrounded in the west and east at a distance of 150 - 400 m from the Attert river. In the east, the stream Rädelsbach flows to the Attert.
At present, a hydraulic and hydro-chemical investigation of the water network is underway, which has not yet been completed.

2.5 Construction project

There are no concrete information on the construction project or the specific use of the site. This overview of the buildings suggests that the entire site can be fully used by constructions. A part of the forest remains.
When submitting plans for the construction project, it is recommended that the information from the preliminary investigation be used and supplemented with reference to the construction project.

2.6 Pipeline situation (Annexe 2)

The management plans for the Post, Creos and the municipality are attached as Annexe 2. Under the asphalted road through the site are private water pipes of 'Luxlait'. In the south-western area, under an unpaved road, is a DN 300 sewer pipe.

3. Topographical situation (Annexe 1, Annexe 4)

The flat surface is located in the northwestern edge of the plateau between the rivers Alzette in the east and the Attert in the northwest. The originally forested area is now being used for agriculture, except the remaining stocks. In the south, the area borders the existing Buusbierg/Bissen industrial estate. The village of Bissen lies south-west of the area.

The peak of the area (274.30 m) is located on the border of the existing industrial estate. From there, the area generally falls off north to Attert. The lowest point of the plan site is located at a height of 249.36 m on the western edge.

Overall, the slope of the area is relatively flat. Only at the western and eastern edge is the gradient to valley cuts larger (see sections in Annexe 4). In the plateau area, the average slope is 0 to 2% to the north. In the peripheral areas (west, east) the average slope is about 10%. In the area of ramps, the slope can rise up to 30% in small areas.

4. Ground structure

4.1. Topsoil (Annexe 3)

According to pedological maps, there are predominantly stony brown soils made of dolomite and stony clayey brown soils and parabrown soils with quartzitic boulders to be found on the site (Annexe 3).

In the southern area, clayey, and heavy clayey brown earth can occur. The stony-clayey and stony-toned brown soils appear as sloping soils in the marginal areas, with a greater gradient towards the Attert river.

These soils are subtypes of brown soil, which differ in composition and mineralogy. The structure is generally an upper humus horizon (Ah) that merges into a mineral subsoil horizon. This B horizon is characterized by the weathering of the source rock and shows a change in colour due to clay and browning. This is followed by the mineral subsoil horizon of the source rock.

The chemical examination of the humus topsoil (agricultural soil up to approx. 0.3 m) as well as the topsoil (0.3 m to 1.0 m) is attached as section 3: Environmental investigations. Evidence of increased geogenic copper contents and tar contents in two places was found in a total of 2 places (Annexe 8.1).

Surface water situation

Due to the fine-grained soil structure (clay sand to silty clay) a high proportion of surface water is to be expected, which can be drained off via trenches and drains into the cuts in the terrain on the western and eastern side of the site and thus derived into the surface water runoff.

4.2. General geological structure (Annexe 3)

The geological situation is based on the geological maps for the map sheet "Mersch" in the old version of the LUCIUS Service Géologique and in the new edition published in 1983 (Annexe 3). The relevant scientific explanations are:

DITTRICH (1984): Explanation of the Geological Map of Luxembourg 1 : 25,000 sheet no. 8 Mersch; Service géologique du Luxembourg Volume XXV

DITTRICH (1989): Basin analysis of the upper Triassic basin of the Trier-Luxembourg Bay; Service géologique du Luxembourg Volume XXVI

Structural geological layout

The research area is located on the north-eastern edge of the Paris Basin and is surrounded by the varisk massif of Ardennes, the Eifel and Hunsrück. As a subsidence zone of the 'Mulde of Luxembourg', younger upper layers of the Triassic were deposited on the Devonian underground in the Mesozoic period (Annexe Dittrich p. 77).

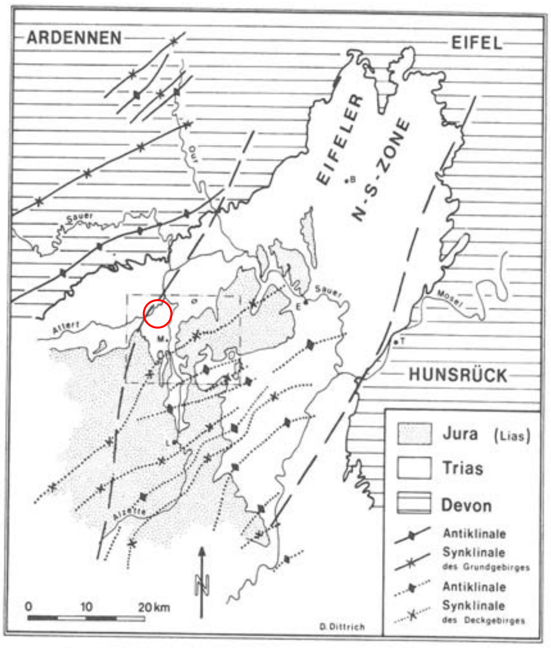

Abb. 28: Geologischer Rahmen des Blattgebietes (ohne Bruchtektonik).

The surface layers reacted to the stretching of the Devonian subsoil through the formation of individual fractonically applied slabs (microtectonics). Essentially NNE-SSW-running faults were formed as shifts and postponements with offset amounts of less than 10 m (Annexe Dittrich p. 79).

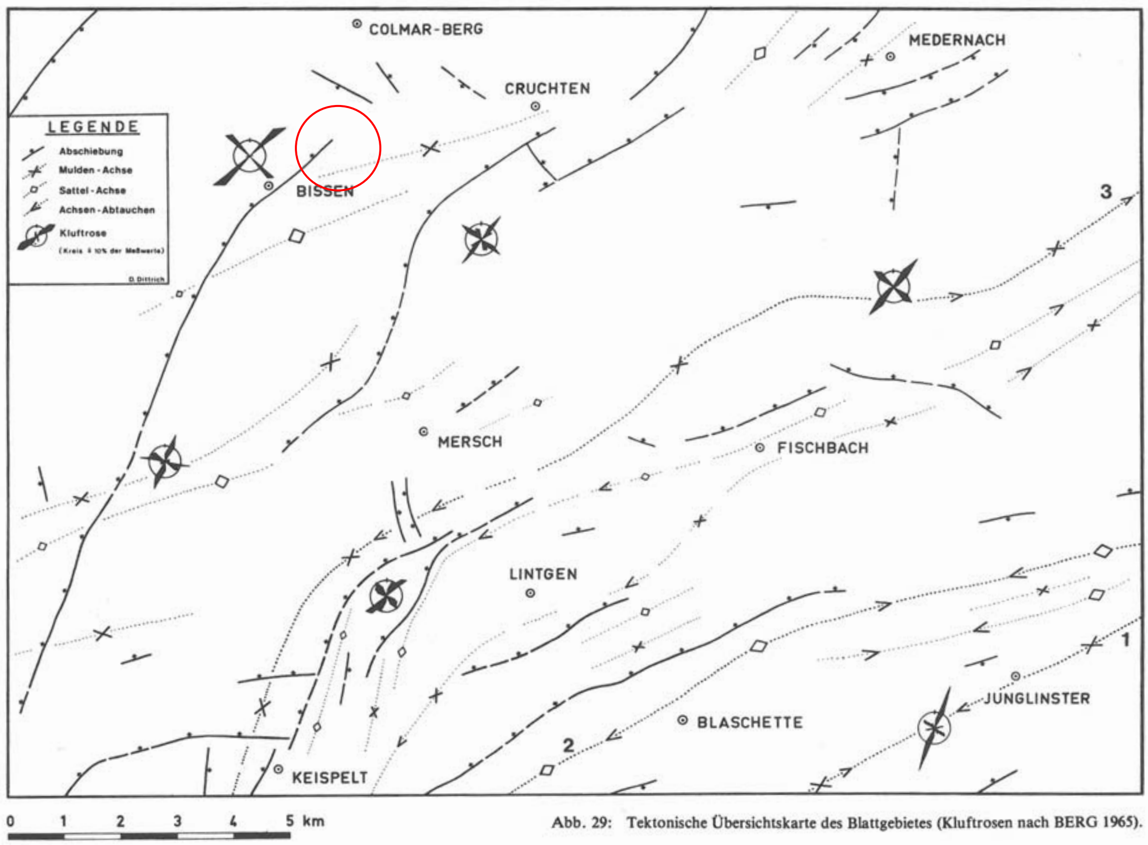

Abb. 29: Tektonische Übersichtskarte des Blattgebietes (Kluftrosen nach BERG 1965).

Correspondingly, NW-SE-running fault lines occur.

On the geological map in the version according to LUCIUS (older version) the study area is bordered by two NW-SE deportations in the northeast and southwest of the area, whereby the study area is to be regarded as a trench structure (Annexe 3).

On the newer geological map (1983) a deportation is registered in the northern part of the investigated area (Annexe 3).

According to the geological map, the layers are stored approx. horizontally (Annexe 3; Geological section).

<u>The drillings and geophysical surveys carried out now showed a situation comparable to the current geological map (Annexe 6.4). Within the scope of geophysical exploration (Annexe 5), it is possible to subdivide the fault into individual fault lines.</u>

Stratigraphic structure

The geological horizons occurring at the site are to be assigned to the middle keuper of the Triassic. From bottom to top, it is the pseudomorphose keuper (km1), the reed sandstone (km2s) and the stone marl keuper (km3) (normal profile as Annexe 6.7).

The sediments of the pseudomorphosis keuper are sediments of a marine sedimentary basin in the arid climatic area with alternating storage of marine sediments and sediments from the adjacent mainland. The later development to the stone-mergel keuper indicates an increase of the marine influence with regular lime deposits.

Pseudomorphosis keuper (km1)

The km1 determines the largest proportion area in the investigated area and is divided into a total of 5 deposition phases, the km1 (1) lying in a horizontal position up to km1 (5) in the slope. These 5 subdivisions of the literature consist of sandy to fine-grained sediments (km1 (1), km1 (3), km1 (5)) or of dolomitic cemented conglomerates (km1 (2), km1 (4)). Overall, sandstones with different degrees of dolomitic cementation and conglomerate inclusions (milk quartz, gravels, clay pebbles) occur. A distinction among these 5 subdivisions depends on the morphological location of the site at the time of deposition.

In the drill cores, the deposits of the pseudomorphosis keuper occur once as alternately solid sandstones in brown-redish colour with green inclusions or thin layers without solid dolomitic binders. In addition, light to greenish sandstones with dolomitic binders and light sandstones to dolomites in thicknesses ranging from a few decimeters to a few meters can be distinguished.

The strength of the sandstones is determined by the formation of the binding agent, i.e. the proportion of dolomite in the pore space, so that the strength and water storage capacity changes with the change of the binding agent or the cement content.

Annexe 6.3 contains the data of the drilling recorder with a measurement interval of 1 cm for the rotary drillings. The green column 'vitesse d`avancement' reflects the increasing change in the strength of the thin layers of sediment as drilling progresses. High drilling progress means a high proportion of clay/marl or a separation area in the solid rock. Low drilling progress indicates a strongly bonded sandstone or dolomite horizon.

Reed sandstone (km2s)

The reed sandstone has been found in the "Rouscht" drilling with a thickness of approx. 1.7 metres. It is difficult to differentiate from the lying sediments of km1 (5) due to the common sandy fine-grained structure. Only if a clear conglomeration horizon is formed at the base of the reed sandstone, which is often to be found at the edge of the Ardennes, a clear separation can take place. These gravely-rock-like horizons were not clearly identified in the drillings in the investigation area, so that there is no delimitation between pseudomorphosis keuper and reed sandstone.

Stone marl keuper (km3) and topsoil (dl)

The stone marl keuper (km3) is easily distinguishable from the more sandy base layers by the alternation of greyish marl and hard stone marl and is superimposed on the border area to the industrial area by a few meters of mighty clay ceilings (dl).

The stone marl is found mainly in the upper drilling metres, in a clearly weathered and decomposed state.

4.3 Geophysical survey (Annexe 5)

A total of 23 geo-electric profiles with a total length of 8.428 km and a depth effect of up to 20 m were created at the site. The results of the geo-electrical survey and the technical report are attached as Annexe 5.

The geophysical survey confirms the results from the drilling (Annexe 6). Two special features resulting from the geoelectrical surveys should be noted.

Environment of drilling R8

In drilling R8, the chemical analysis of the surface sample shows a low concentration of tar in the soil. At the same time, the geophysical survey in this area (profile line 12) shows a disturbed soil structure. Further, drilling in the vicinity of drilling R8 and profile line 12 will be used to determine whether soil masses have been piled up in this area.

Soil distortion in the eastern area of the site

The deportation in the eastern section between drillings D14 and F5 could be subdivided with the geoelectric survey (profile line 13) into individual fault lines, which are to be regarded as deportation coulters.

4.4. Earthquake situation (Annexe 3)

According to Belgian standards, the site is located in the transition from earthquake zone 1 PGA (Peak Ground Acceleration) = 0.05 m/s^2 to earthquake zone 0 (PGA = 0 m/s^2). According to detailed photographs of the "Hazard Map for Belgium" (1995), the location is in the area of PGA = 0.03 m/s^2 (Annexe 3).

Overall, there are no relevant earthquake shocks to be expected in the planned area.

4.5. Soil strength

The soil strength was investigated by means of ram core soundings, heavy pile driving tests and drilling expansion tests according to MENARD (see also Section 2: Geotechnical Investigations).

In summary, Annexe 6.5 shows an overview map with the thickness of the weathered surface layers. In the area of the pseudomorphosis keuper, the weathered surface layers above the solid rock are only a few metres thick. The thickness of the soft to semi-solid surface courses in the area of the stone marl keuper and in the valley areas increases to between 3 m and 7 m. In these horizons, the breaking and compressive strength is reduced by weathering and water content. High to very high rock strengths occur in the horizontal and groundwater-free solid rock, which enable any kind of foundation, even with higher loads.

5. General groundwater situation

Upper shell limestone (mo)

The dolomite package of the upper shell limestone (mo2), approx. 42 m thick, beneath the layers of the pseudomorphosis keuper (km1), is potentially suitable for water supply with generally high yields. The ground clearance to this aquifer is approx. 50 m at the site (standard profile as Annexe 6.7). The water from the fissures of the dolomite can be classified as hard to very hard due to the high content of calcium and hydrogen carbonate.

The following assumptions on the groundwater situation can be made with regard to the geological layers at the site:

Pseudomorphose keuper and reed sandstone (km1, km2s)

The formation of light water horizons (Annexe 6.6) has been demonstrated by the formation of layers of fine sand, conglomerates and sandstones or dolomitic sandstones with marl layers. Due to the fine-grained structure, the pore permeability is low and the yield is also considered to be low.

Stone marl keuper (km3)

The stone marl keuper (km3) has no significance due to its peripheral distribution in the investigated area and is generally considered to be not very water-bearing. Only in the small fissures and the broken stone marl banks can expect a modest water supply and a high sulphate hardness of the groundwater.

Groundwater levels (Annexe 6.6)

The following groundwater levels were measured in the pseudomorphosis keuper (drillings F3, F7) and in the stone marl keuper (F5, F6).

Drilling	**Groundwater level (m)**	**Groundwater level (mNN)**
F3	10.79 (01/02/2018)	248.11
F5	8.80 (20/02/2018)	255.64
F6	2.97 (20/02/2018)	259.28
F7	17.23 (01/02/2018)	243.25

In the drillings F5 and F6, access to layered water near the surface is not excluded. It is recommended to carry out a further cut-off date measurement in the hydrological summer season (01/05/2018 and 31/10/2018). No unambiguous and stable groundwater level up to a drilling depth of 20 m was found in drillings F1, F2, F4, F8 on the ridge of the site.

The chemical analysis of the groundwater sampled is shown in Annexe 8.3. The stratified water encountered shows an agricultural influence in the levels F3, F6, F7 due to the increased content of nitrate, nitrite and ammonium. Similarly, in the levels F3, F6, indications of iron and mange in the water resulting from chemical soil weathering were found. Due to its high carbonate content, the water can be classified as "hard" at all levels. In level F7 lime-solving carbonic acid was found, which resulted in a classification into the category "XA1" as weakly aggressive to concrete. Traces of heavy metals were detected in the water from level F6, which, like the findings from the topsoil sampling with increased tar content, indicate a local embankment or pavement consolidation.

In general, no groundwater situation was encountered that could influence the construction project. With regard to a possible use of groundwater, the horizons of the upper shell limestone (mo2) would have to be explored at a depth of approx. 50 to 80 m (see Section 4: Geological risks and geopotentials).

6. Potential land use (Geological risks and Geopotentials)

Structures

The existing utilisation structure indicates that the site is being used by buildings over its entire area. The site situation determined so far, does not restrict this type of use.

On the basis of the soil data, it can be determined that in the peripheral areas of the planning area there are soft soil horizons, which can have an influence on the foundation of the buildings. In this area, it makes sense to construct ancillary buildings (energy, water supply, water treatment, infrastructure), leisure areas (parks, sports areas) and traffic and parking areas (Annexe 9). On the western side of the site, photovoltaic power generation is possible.

In the other and central areas of the plane surface, a solid base can be achieved with the usual use of construction machinery, on which any form of foundation is possible even with high load transfer and with a minimum of soil deformation (settling).

The relief of the site requires the construction of building sites by excavation and deposit (Annexe 9: Cut and Fill). The excavation can be carried out in dry soil horizons that are only influenced by stratified water. The surface water on the building sites can be drained off into the peripheral areas. The soil masses resulting from the excavation can be used to model the total surface area or, in the case of consolidation, to create terrain platforms (see Section 4: Geo Risks and Geopotentials).

Private water supply

Due to the location of the site above the upper shell limestone, local water supply from wells approx. 70 m deep is potentially possible. Due to the high content of hardening agents, the water must be descaled before it is used for technical purposes.

In addition, it is theoretically possible to use surface water from Attert, about 150 m until 600 m away. Hydraulic and hydrochemical investigations are carried out in this respect.

Geothermal potentials

The pseudomorphose keuper (km1) and the shell limestone (mo) can be used for the transport of energy and cooling via heat exchanger systems. The geothermal potentials can be represented by empirical values and geophysical literature data. Usually, double U-sensors with a depth of approx. 100 m are used as heat exchangers.

Part 2: Geotechnical examination

7. Geotechnical examination

Within the scope of the geotechnical investigation,

9 pile core drillings DN80/60 in the surface layers,
15 dynamic drillings DPH in the surface layers,
8 rotary core drillings up to 20 m with 8 x 8 side pressure tests

were carried out (Annexe 6).

Soil and solid rock samples were taken from the drillings for mechanical and chemical testing in the laboratory:

16 chemical tests of the topsoil (Annexe 8.1),
31 chemical tests for calcium and sulphate (Annexe 8.2),
7 determinations of soil type (Annexe 7.1)
and 6 direct shear tests (Annexe 7.2)

were carried out.

The soil mechanics statements made here are only valid for the immediate vicinity of the drillings. Deviations from the drilling results cannot be ruled out due to the high distance between the investigated sites.
Due to the size of the total area, the recommendations presented here cannot be regarded as conclusive and must be coordinated in detail with the planner to the concrete construction project. It is proposed to carry out detailed investigations in connection with the development of the planned area, depending on the construction project.

8. Result of the soil mechanical tests

8.1 Ground structure

Appendices 6.1 to 6.3 are showing the results of the drillings and in Annexe 6.4 the results are summarized.

<u>Arable soil and topsoil</u>
The humic topsoil (arable soil) has a thickness of approx. 0.3 m and is classified in soil class 1 according to DIN 18300. The humic topsoil is to be weeded off during removal and stored laterally for later re-covering.
The topsoil with a depth of 1 m to approx. 2 m from soft to stiff consistency and belongs to soil class 4 according to DIN 18300. In the area of the pseudomorphosis keuper, the topsoil is

finely sandy and clayey in the area of the stone marl keuper.
The excavated topsoil can later be used for ground-modeling. Technical use as substructure material is only possible to a limited extent. The fine sandy topsoil (type SW, UL from the subarea of the pseudomorphosis keuper) can be improved or consolidated by lime/cement. The clayey topsoil (soil type TA, TM from the subarea of the topsoil) is only suitable for modelling and covering.
The arable and topsoil are generally unpolluted after a chemical examination (see Section 3: Environmental investigations). No pesticide residues have been detected. In the drillings F8 and RKS 7 occurres increased geogenic copper content. In drilling F6, high tar fractions in the soil were found to indicate local pavement. Slightly increased tar fractions occur in the drilling RKS 8, which, together with the geophysical survey indicate local soil fillings. Further investigations in this area are recommended.

Weathering zone
The weathering zone between the topsoil and solid rock is stony in the area of the stone marl keuper and can be assigned to soil groups 3 and 5 according to DIN 18300. In some areas hard sandstones and dolomites of soil class 6 can be found.
The excavated soil masses of the weathering zone can later be used for modelling. Technical use as a substructure material is only possible to a limited extent, since the solid excavated bodies dissolve into fragments and sand under mechanical stress.

Solid rock
The solid rock can be found in the area of the plateau at a depth of 1 m to 3 m and consists of alternating sandstone horizons with varying binders (clay, lime). According to DIN 18300, the solid rock can be assigned to soil classes 6 - 7. Uniaxial compression tests for the classification of the solid rock were not carried out in addition to the drilling expansion tests according to MENARD, as the homogeneous areas have only a small thickness.

8.2 Near-surface groundwater, surface water

Only locally inferior stratified water horizons occur in the stone marl keuper (km3) and in the pseudomorphosis keuper (km1) (see Section 4). A contiguous mountain water level could not be measured in the 20 m deep drillings. It is assumed that the mountain water level develops between the receiving waters (Annexe 6.4).
The stratified water was sampled and chemically tested in the drillings F3, F4, F6 and F7.

Drilling	Groundwater level (m)	Groundwater level (mNN)
F3	10.79 (01/02/2018)	248.11
F5	8.80 (20/02/2018)	255.64
F6	2.97 (20/02/2018)	259.28
F7	17.23 (01/02/2018)	243.25

In the drillings F5 and F6, access to layered water near the surface is not excluded. It is recommended to carry out a further cut-off date measurement in the hydrological summer season (01/05/2018 and 31/10/2018). No unambiguous and stable groundwater level up to a drilling depth of 20 m was found in drillings F1, F2, F4, F8 on the ridge of the site.
Overall, the construction projects in connection with the excavation or foundation pits are not affected by groundwater or stratified water. Due to the fine-grained structure of the topsoil, a relatively high proportion of surface water can be expected, which has to be drained off in controlled ditches and drains.

As part of the chemical test for concrete aggressiveness, lime-solving carbonic acid was found at level F7, resulting in a classification into the category "XA1", as weakly aggressive to concrete (Annexe 8.3).

8.3 Soil mechanical characteristics

In the course of soil mechanical tests on soil samples, the types of soil in the topsoil and weathering zone were classified and investigated in the laboratory. Altogether, the following types of soil could be distinguished, although these can only be roughly classified by geological structure.

Soil group	Samples	Description
A	R9-B3-1-3	Fine sands of the pseudomorphose keuper, slightly silty, slightly gravelly
B	F3-B3-2.8-4.3 F1-B3-2.0-2.7	Mixture of silt and fine sand of the pseudomorphose keuper
C	R4-B3-1.2-2.6	Topsoil and very clayey topsoil of the stone marl keuper
D	R3-B2-1.5-2.0 R1-B3-1.5-2.5	Clays and slogs of the pseudomorphos keuper, fine sandy
E	F7-B3-1.9-2.4 R8-B3-1.0-2.1	Clays and silts of the pseudomorphosis and stone marl kupper, marly
F	F5-B3-2.2-3.6	Marl of the stone marl keuper, fine sandy
G	F6-B3-2.0-3.5	Clay of stone marl keuper, fine sand and marly

The following classification of the soil masses encountered can be carried out on the basis of the field recordings:

Frost sensitivity according to ZTVE-StB 94 (1997 version):

According to DIN 18196, soils with a fine-grained content of 5% or more are to be classified as sensitive to frost or very sensitive to frost. As a general rule, the formation level for structures that have been built close to the surface and for paved surfaces must be laid at a minimum frost protection depth of 0.9 m below the intended top edge of the terrain in natural soil or on a load-bearing frost protection layer.

Soil characteristics of excavation materials for structural purposes

Direct soil-mechanical laboratory investigations for the determination of the soil type and shear strength were carried out within the framework of the foundation soil investigation on a total of 7 different soil types, so that according to the laboratory data, the available experience and in accordance with DIN 1055 and TÜRKE (1999) the following soil parameters are used for the soil horizons encountered.

Characteristic soil properties according to DIN 1055 and Annexe 7

Soil group	**Soil type DIN 18196**	**Consistency**	**Bulk density (kN/m³)**	**Friction angle (°)**	**Cohesion (kN/m²)**	**Soil class DIN 18300**
A	SUU	Loose	(17 – 18)	(30° - 32°)	(0)	3
B	ST-TL	Semi-solid	(21 – 22)	26.7° / 26.4° (27.5°)	89.7/51.8 (5)	4
C	TA	Stiff	(19)	16.6° / 18.7° (17.5°)	14.5 / 8.9 (10)	4
D	TL	Semi-solid	(21)	25.1° / 26.0° (27.5°)	102 /36.2 (5)	4
E	TM	Semi-solid	(20.5)	17.2° / 11.7° (22.5°)	52.3/49.8 (10)	4
F	TM	Stiff	(19.5)	18.1° / 27.2° (22.5°)	39.3 / 8.2 (5)	4
G	TM	Stiff	(19.5)	27.4° / 27.8° (22.5°)	2.4 / 0.3 (5)	4

The values given in () correspond to the table values of DIN 1055.

The friction angle determined in the laboratory corresponds approximately to the recommendations of the standard. Only in soil group E (weathering marl close to the surface) are the lower values measured in the laboratory. The Cohesion coefficients measured in the laboratory are on average and for fracture conditions higher than the recommendations in the standard. Cohesion coefficients decrease considerably after breakage.

For the further use of data, the application of characteristic values is recommended. Due to the differences between the weathering soils from the pseudomorphose keuper km1 (soil groups A, B, D), the stone marl keuper (soil groups E, F, G) and the topsoil (soil group C) a separate evaluation is carried out.

Characteristic value	km1 (A, B, D)	km3 (E, F, G)	dl (C)
Soil type	SUU, TL	TM	TA
Bulk density	20.5 – 21.5 kN/m³	20.5 kN/m³	18 – 19 kN/m²
Friction angle	26°	18°	18° - 19°
Cohesion	36 kN/m²	39 kN/m²	9 kN/m²

Soil classes

It is recommended that soil class 1 for arable land and soil class 4 for topsoil, according to DIN 18300, be used as a basis for excavation. Soil class 3 - 4 can be used for the weathering zone. Soil class 6 - 7 shall be used for excavations in solid rock.

Soil usage

The fine-grained soil masses encountered are to be used for modelling. After quality assessment and compaction or consolidation, the mixed-grained soil masses can be used for the production of ground platforms.
For the removal of the soil masses, the chemical examination of the topsoil has shown that the soil excavation is generally considered to be free of pollutants and can be stored at the soil dump (see section 3: Environmental investigations). In the vicinity of the drillings RKS 8 and F6, additional investigations must be carried out with regard to the tar content.

8.4 Chemical Aggressiveness

The deposition of sediments in the arid deposit chamber at the time of the keuper leads to the formation of chemical compounds such as salts and sulphate. To clarify this situation, 16 soil samples from a depth of up to 1 m were examined for all environmentally relevant compounds and 31 soil samples from a depth of 1 m to 20 m for sulphate. At the same time, water samples were taken in the expanded levels F3, F5, F6 and F7 and tested for environmentally relevant compounds as well as for aggressiveness against concrete.

The chemical examination of the samples from the topsoil to a depth of 1 m did not yield any relevant concentrations of sulphate and chloride (Annexe 8.1). In this horizon the sulphate and chloride compounds were dissolved in the course of chemical weathering and soil formation. A recrystallization by capillary ascending seepage water was also not detected.
In the deeper soil samples of more than 1 m, relevant sulphate contents > 2,000 mg/kgTS were detected at foundation-relevant depths of up to 5 m below ground level (Annexe 8.2). Due to the concentration above 3,000 mg/kgTS, the classification in 'weak to heavily attacking soil XA2', according to DIN 4030, must be assessed.
The chemical examination of the stratified water samples taken shows an increased calcifying carbonic acid only at level F7, which allows an allocation to the assessment class XA1

(weakly attacking).

Overall, the concrete foundations have to be built with a cement that has a high sulphate resistance (HS) and is effective against lime-solving carbonic acid. In general, the concrete foundations must be equipped with increased resistance to concrete aggressive water (XA1).
Drainages are to be laid at the lower edge of the base layers, under the floor slabs, which limit the accumulation of seepage water under the concrete slabs. This significantly restricts the theoretical possibility of the formation of spring pressures under heated rooms by evaporation of sulphate-containing leachate.

9. Soil strength

In drillings F1 - F8, 8 drilling expansion tests were carried out according to MENARD. The results of the tests are attached as Annexe 6.3 and summarised in the table of Annexe 7.3. Accordingly, the following classification can be made on the basis of soil type and **breaking strength (pl-value)**:

Soil type	**Breaking strength (MN/m²)**	**Designation**
Clay, loam	< 0.7	Soft
	1.2 – 2.0	Firm
	> 2.5	Very firm - hard
Sand	< 0.5	Loose
	1.0 – 2.0	Medium density
	> 2.5	Dense
Marl, lime marl	1.5 – 4.0	Soft - stiff
	> 4.5	Firm
Rock	2.5 – 4.0	Weathered
	> 4.5	Softened
	50 - 80	Unweathered

Annexe 7.3 shows the minimum, maximum and mean value in relation to the local depth. Accordingly, the soil in general (average) from a depth of 2 m is to be regarded as stiff to firm and thus suitable for the near-surface foundation of buildings.
The strength increases rapidly with depth. Generally, a rocky character of the soil can be expected from a depth of approx. 6 m in the area of the pseudomorphosis keuper.

Deeper weathering zones with a stiff consistency occur in the area of the stone marl keuper (drillings F5, F6). From a depth of approx. 8 m the rocky character also prevails in the stone marl keuper.

10. Building Foundation

The foundation instructions are based on the proven soil structure and the strength of the various soil horizons.
For the execution of the foundation, the generally valid rules of good construction practice apply with regard to the compaction of base layers, insulation of the building structure and the controlled drainage of surface and ground water. Deviations from the findings or changes in the recommended procedure must be agreed with the soil expert.

10.1 General foundation situation

The drillings in the area of the plateau reveal a relatively small cover layer (topsoil, weathering zone) of 1 - 3 m, which is softened on the surface (up to 1 m). Below the surface course follows the softened solid rock. <u>The foundation can be carried out without restriction as area foundation, line foundation, point foundation or pile foundation depending on the building load and the load distribution.</u>
<u>A sustained inflow of groundwater or stratified water is not to be expected in the foundation half space.</u>
In the case of foundation, a distinction must be made between foundation in the weathering zone (softlayer) and foundation in solid rock (rocklayer). The foundation in the weathering zone shall be estimated on the basis of the soil characteristics in accordance with Section 7.3 and the foundation in solid rock according to the breaking strengths in accordance with Section 8.

10.2. Buildings: Model-like foundation situation

The following load cases were specified for the foundation of the buildings:

10.2.1. Permissible ground pressure for column loads

The column loads support the roof structure and the ceilings and are expected to be between 1,000 kN and 10,000 kN according to the customer's specifications. The load transfer can theoretically take place as a single foundation, line foundation, area foundation and deep foundation (pile, ballast) depending on the soil structure.

According to the soil-mechanical characteristics, the following permissible soil pressures can be specified with regard to base fractures for individual foundations **for the weathering zone**. <u>The embedment depth is assumed to be 1 m and 2 m. If the integration depth is different, other calculation bases must be used. The calculation is based on the characteristic shear parameters according to Section 7.3. and a minimum foundation width of 1 m for a single</u>

foundation. The basis for the design rating is the estimated stiffness figure for the soil of approx. 5 MN/m² (very stiff to semi-solid soil) at a depth of approx. 1 m.
The situation in the area of the "dl" soil group is not taken into account here, since this area in the eastern part of the total area is to be regarded as small-scale and inhomogeneous and is to be considered individually for each foundation case.

Estimation of the permissible soil pressure and the bedding ratio for the weathering zone (softlayer)

Binding depth	**Soil type**	**Perm. ground pressure (kN/m²)**	**Bedding factor (MN/m³)**
1 m	Km 1	approx. 1,000	approx. 10
	Km 3	approx. 600	approx. 10
2 m	Km 1	approx. 1,400	approx. 10
	Km 3	approx. 700	approx. 10

10.2.2. Foundation concepts for various load cases

Within the framework of the project presentation, example load cases for column loads were presented, which are to be taken into account in the geotechnical concept. It is expressly pointed out that in the concrete case, the size of the foundation slab must be measured on the basis of the local geotechnical parameters. The following estimate is only indicative.

Load case 1,000 kN and 2,500 kN
The column load from 1,000 kN to 2,500 kN can be carried on a single foundation (foundation slab) in the weathering zone at a minimum depth of 1 m and on a minimum area of 1 m x 1 m. The permissible soil pressures between 600 kN/m² and 1,400 kN/m² must be taken into account and the size of the foundation slab must be adapted accordingly.

Load case 5,000 kN, 7,500 kN, 10,000 kN
Due to the expected size of the foundation slab, the column load from 5,000 kN to 10,000 kN cannot be removed in the weathering zone. The foundation **must be carried out in solid rock** on the basis of the determined breaking strength. In this context, a safety margin of 3 shall be taken into account when taking into account the pl values in accordance with Sections 8 and 7.3 of this Annexe and at the same time a safety margin of 2 when taking into account the pf value in accordance with 7.3 of this annexe. In addition, the shear strength and embedment depth must be used to prove the basic breaking resistance. In general, it is recommended to carry out a supplementary geotechnical investigation at the site of load transfer for loads of 5,000 kN or more. The available measured values can be used for preliminary measurement.

Load case	pf-value* / pl-value*	Foundation plate *
5,000 kN/m²	> 5 MN/m² / > 8.5 MN/m²	Approx. 2 m² (1.4 m x 1.4 m)
7,500 kN/m²	> 5 MN/m² / > 8.5 MN/m²	approx. 3 m² (1.7 m x 1.7 m)
10,000 kN/m²	> 5 MN/m² / > 8.5 MN/m²	approx. 4 m² (2 m x 2 m)

* is to be determined at the location of the load transfer

10.2.3. Area loads due to concrete floors

The concrete floors bear the traffic loads, dead load, machine load and, in the case of load-bearing floor slabs, possibly also the building structure. The loads are specified by the customer with 10 kN/m² to 25 kN/m² and indicate that structural loads of the building are not planned to be transferred to the floor area.
The load is transferred to the subsoil over a wide area. The subgrade reaction modulus is the characteristic parameter for the design of the base plate and results from the measurement of the MENARD module of the drilling expansion tests.

After the drilling expansion tests and the assumption of an excavation of approx. 1.0 m and a highly compacted base layer of at least 0.3 m, the following bedding numbers can be given for a base plate 20 m x 40 m. For a different building size, other initial values must be used as a basis and local inhomogeneities must be taken into account. The calculation is based on a stiffness number of the soil of 5 MN/m². The following estimate is only indicative.

Load case	Bedding factor (MN/m³)
10 kN/m²	No soil reactions due to excavation relief of approx. 15 kN/m²
15 kN/m²	
25 kN/m²	approx. 2 MN/m³, with an average settlement of 1.3 cm
50 kN/m²	approx. 2 MN/m³, with an average settlement of approx. 2 - 3 cm

Due to the small size of the upper soil zone, only minor soil reactions can be expected, even with area loads. It is expressly pointed out that in the concrete case, the size of the foundation slab must be measured on the basis of the local geotechnical parameters.

10.3 Traffic areas

Ev2 > 45 MN/m² or Evd > 25 MN/m² has to be proven as a subgrade for the technical construction of the road. For this purpose, the soil must be removed to a depth of approx. 1.0 m, the sole must be compacted, covered with a fleece and built up with antifreeze material up to the asphalt base layer provided. If at a depth of approx. 1 m there is no ground with a

minimum strength of 45 MN/m² (Ev2) or 25 MN/m² (Evd), a soil exchange or another improvement of the ground planum is to be carried out.
The first compaction layer (depth approx. 0.7 m) of the frost base layer should have a strength of Evd > 25 MN/m² or Ev2 > 45 MN/m². The top layer (depth approx. 0.4 m) as a formation layer for the asphalt base course should have a strength of approx. Evd > 60 MN/m² or Ev2 > 120 MN/m².

10.4 Sewer and pipe shafts

For the trunking and cable ducts with a depth between 1 m and 3 m, removal, laying and installation are possible without restrictions. The depth/width of the trench has to be determined by the customer. The flanks of the trenches shall be embanked to a depth of approx. 1 m with an angle of maximum 60°.

10.5 Production of terrain platforms

The construction of terrain platforms is unavoidable due to the slope in north-south direction as well as to the valleys in the edge area. Here it is possible to build platforms for each building or to create a coherent platform on the high ground of the site and from there stepped platforms to the side valleys.

Version 1: Building platforms
In the production of differentiated platforms for the construction sites, the general terrain gradient of approx. 2% on the plateau area is maintained. The roads and supply lines adapt to the general terrain slope.

Procedure
At the respective building sites, a wedge-shaped cut is made in the ground for the building site. This results in a height offset of the buildings in north-south direction. With the wedge-shaped cut of the building site, the building's partial surface on the mountain side is located in the natural soil and on the solid subsoil of the weathering zone or the solid rock. The valley-side part of the valley is located in the upper floor area or above the natural terrain level on a poured platform. In order to avoid settlement differences, the foundation on the valley side must be of comparable strength as the foundation half space in the mountain side area. In the case of single foundation and strip foundation, the procedure is therefore comparable to that of the foundation on the mountain side and is only possible with sub-concrete underneath the foundations, which extends into the solid subsoil. The base slab or, in the case of foundation via a load-bearing base slab, it is possible to solidify the fine sandy soil from the excavation with 3 - 6% cement using a soil mixer. To this end, additional laboratory tests must be carried out to determine the aggregate quantity of cement and the achievable solidification.

To reduce the differences in the stability of the ground planum, the buildings can be aligned with the long side in an east-west direction.
The utilisation of the soil for the contract is to be assessed for each construction site according to the structural classification of the demolition material.

In the area of the valley slopes of the terrain, the situation is comparable to that on the plateau. In these areas, the slope gradient is higher, resulting in deeper ground incisions or higher platforms. For the pouring of platforms above a valley level of 2 m, it is recommended to construct retaining walls on the valley side (annexe 9.1). Planning can only be carried out if the size and location of the building are known.

Summary
The advantage of this procedure is a low volume of mass movement and a small volume of transport routes for the soil masses. The disadvantage is that there are different levels of the buildings with different duct connection heights.

Version 2: Terrain platform
An example of the creation of a uniform platform for all buildings on the ridge of the building site is attached as annexe 9. The platform (= earth planum floor slab) is placed at the level of 267 mNN.
The excavated soil masses are relocated and built up in the direction of the valley, if the structural characteristics permit this. The excavated soil masses can only be used directly for the construction of the subsoil on the valley side of the building if they are mixed or coarse-grained. Due to the predominantly fine-grained structure, this is only to be expected to a minor extent in the pseudomorphosis keuper.

Summary
The advantage of this approach is a uniform building height on the high plateau of the site. The disadvantage is large soil masses and long tracks for the recycling of the soil masses, possibly with the use of a soil improvement.

10.6 Drainage and seepage of surface water

Day water from sealed surfaces, roofs must be collected and fed to the sewerage system (dirty water) or Attert (roof water, traffic areas) after cleaning. The water cannot be seeped on the surface of the plan as the infiltration capacity is not given due to the fine-grained soil structure.

Part 3. Environmental investigation:

11. Soil testing

11.1 Topsoil

In the course of the drilling work, 8 soil samples from the arable soil were taken from the topsoil to a depth of 0.3 m and 8 soil samples from the top soil at a depth of 0.3 m to 1.0 m and examined for the relevant environmental chemical parameters (annexe 8).
The following shows the minimum, maximum and average values that have been determined. At the same time, a comparison is made with Luxembourg's usual environmental standard for a natural soil (SW1 value) and the maximum value for storing the soil on a landfill site (value type A).

Parameter	Unit	MIN	MAX	Average	oSW1	Type A
Organics (TOC)	mg/kg	1090	20500	8028.1		30000
Soil						
cyanide	mg/kg	<0.3	1.3		5	
arsenic	mg/kg	3.7	14	7.5	20	
lead	mg/kg	5.5	27	13.7	100	
cadmium	mg/kg	<0.2	0.2		1	
chromium	mg/kg	17	53	35.9	50	
copper	mg/kg	5.2	100	27.3	50	
nickel	mg/kg	12	47	29.5	40	
mercury	mg/kg	<0.05	0.06		0.5	
thallium	mg/kg	<0.1	0.3	0.2	0.5	
zinc	mg/kg	31.7	159	78.7	150	
mineral oils organics	mg/kg	<50	310		100	300
poly aromatic hydrocarbons	mg/kg	<0.05	2087		1	10
chlororganics	mg/kg	<0.1	<0.1		0.1	
BTEX	mg/kg	<0.1	<0.1		0.2	3
PCB	mg/kg	<0.01	<0.01		0.01	0.2
pesticide	mg/kg	<0.2	<0.2		0.5	
Eluat						
chloride	mg/l	<2.0	7.5		40	250
sulphate	mg/l	<2.0	3.1		200	1500
phenols	mg/l	<0.01	<0.01			0.05
fluoride	mg/l	<0.5	<0.5		1	1.5
antimon	mg/l	<0.005	<0.005			0.05
arsenic	mg/l	<0.005	<0.005		0.01	0.04
barium	mg/l	<0.01	0.02			2

lead	mg/l	<0.005	<0.005		0.01	0.1
cadmium	mg/l	<0.0005	<0.000 5		0.001	0.005
chromium	mg/l	<0.005	<0.005		0.01	0.075
copper	mg/l	<0.005	0.008		0.02	0.15
molybden	mg/l	<0.005	<0.005		0.002	0.1
nickel	mg/l	<0.005	<0.005		0.01	0.1
mercury	mg/l	<0.0002	<0.000 2		0.0002	0.001
selen	mg/l	<0.005	<0.005		0.004	0.02
zinc	mg/l	<0.05	0.18		0.1	0.3

The increase in soil standards observed during the analysis of mixed samples was subjected to an extended investigation. This resulted in the following results (plan of Annexe 8.1).

Parameter	**Unit**	**F4-B1-0.5-0.2**	**R8-B1-0.05-0.25**	**F6-B1-0-0.2**	**R5-B1-0-0.3**	**F8-B2-0.3-0.9**	**R7-B2-0.3-0.9**	**oSW1**	**Type A**
Soil									
arsenic	mg/kg					8	14	20	
lead	mg/kg					7.2	16	100	
cadmium	mg/kg					<0.2	<0.2	1	
chromium	mg/kg					38	48	50	
copper	mg/kg					76	100	50	
nickel	mg/kg					40	38	40	
mercury	mg/kg					<0.05	<0.05	0.5	
zinc	mg/kg					141	133	150	
mineral oil	mg/kg					< 50	< 50	100	300
naphthalin	mg/kg	< 0.05	< 0.05	59	0.11				
Acenaphthylen	mg/kg	< 0.05	< 0.05	<5	<0.05				
Acenaphthen	mg/kg	< 0.05	< 0.05	72	<0.05				
Fluoren	mg/kg	< 0.05	< 0.05	110	<0.05				
Phenanthren	mg/kg	< 0.05	0.32	470	<0.05				
Anthracen	mg/kg	< 0.05	< 0.05	120	<0.05				
Fluoranthen	mg/kg	< 0.05	0.95	430	0.09				
Pyren	mg/kg	< 0.05	0.59	280	0.1				
Benzo(a)anthracen	mg/kg	< 0.05	0.46	160	<0.05				
Chrysen	mg/kg	< 0.05	0.44	110	<0.05				
Benzo(b)fluoranthen	mg/kg	< 0.05	0.52	77	<0.05				
Benzo(k)fluoranthen	mg/kg	< 0.05	0.25	40	<0.05				
Benzo(a)pyren	mg/kg	< 0.05	0.45	82	<0.05				
Dibenz(ah)anthracen	mg/kg	< 0.05	0.11	14	<0.05				
Benzo(ghi)perylen	mg/kg	< 0.05	0.27	28	<0.05				
Indeno(1,2,3-cd)pyren	mg/kg	< 0.05	0.31	35	<0.05				
poly aromatic hydrocarbons	mg/kg	< 0.05	4.67	2087	0.3			1	10

The follow-up investigation shows that there are deposits with elevated tar parts in the vicinity of the R8 and F6 holes. In the vicinity of drilling F6, this can be traced back to a pavement or to the local dirt road, which is partially asphalted. In the vicinity of the drilling R 8 at the same time the geophysical measurement shows a change of the soil structure. Here a local landfill with ground masses is not excluded, which is to be investigated by further drilling.
At the same time, in the vicinity of drillings F8 and R7, increased copper concentrations are to be expected, which according to the current explanation are to be regarded as geogenic.

11.1.1. Soil Ecological Assessment

Heavy Metals
Increased copper concentrations of 76 mg/kgTS or 100 mg/kgTS have been detected in the upper bottom zone of drillings F8 and R7. According to the Luxembourg regulations for the assessment of soil contents, multifunctional use is no longer possible only with a copper value of 100 mg/kgTS (oPw1 value). According to the waste management regulations, the copper value does not restrict the deposition on a Luxembourg landfill site, as the eluate value for copper complies with the limit value. The locally increased copper value in the topsoil is safe.

Mineral oil hydrocarbons
Checking the increased content of petroleum hydrocarbons in the topsoil of drillings F8 and R7 does not suggest a local load above 100 mg/kg TS.

Tar components (polycyclic aromatic hydrocarbons)
In the area of the topsoil, increased to high concentrations of tar components of 4.67 mg/kgTS or 2,087 mg/kgTS have been detected in the drillings R8 and F6.
Since there is a dirt road with local asphalt sealing in the vicinity of the drilling F6, a local distribution of the asphalt residue on the ground is to be found. This section would have to be considered separately in the context of soil excavation. Further, soil analyses are recommended in the vicinity of the drilling R8.
According to the Luxembourg regulations for the assessment of soil contents, a multi-functional use is only possible with a tar content of 10 mg/kg TS for the sum of the 16 individual substances and 0.5 mg/kg TS (oPw1 value).
The waste technical limit value for the deposition of the soil on a Luxembourg landfill site is 10 mg/kgTS, so there are no restrictions for the vicinity of the drilling R8.

Organochlorine compounds, aromatic compounds, cyanides, plant protection products
The test values for organochlorine compounds (PCB, LHKW), volatile aromatic compounds (BTEX), cyanides, plant protection agents (DDT, HCH, pesticides) are adhered to. The soil is not contaminated by pesticides.

Summary
The chemical examination of 16 soil samples (16 sites) shows that, in relation to the boundaries of the plots, the topsoil is not contaminated over the respective area of a plot. Soil contamination occurs locally on copper or on tar components that can be contained (environment F6, R8) or do not restrict the multifunctional use of the soil. The use of plant protection products cannot be proven.

11.1.2. Waste management assessment

The soil masses can be recycled on the site or deposited at a landfill site in Luxembourg. The detected soil contents do not limit the utilisation of the soil.

11.2 Solid rock

For the solid rock, 31 soil samples were taken according to geotechnical criteria to determine the calcium and sulphate content of the soil (section 8.2).
Elevated geogenic sulphate levels were found in the drill cores. Similarly, local and increased geogenic concentrations of heavy metals in the keuper deposits are not completely excluded. The investigations to date on stratified water do not reveal any significant evidence of heavy metals.

12. Layered water and groundwater

In the course of the geotechnical exploration, the contiguous groundwater level in the area of the plateau up to the final drilling depth of 20 m was not reached. In the drillings, seepage water accumulations close to the surface and stratified water in deeper horizons were unlocked. The observation wells F3, F5, F6 and F7, which have been built into the valley cuts, show completely different water levels, which is typical for stratified water. A continuous groundwater pressure surface cannot be constructed.

Drilling	Groundwater level (m)	Groundwater level (mNN)
F3	10.79 (01/02/2018)	248.11
F5	8.80 (20/02/2018)	255.64
F6	2.97 (20/02/2018)	259.28
F7	17.23 (01/02/2018)	243.25

In the drillings F5 and F6, access to layered water near the surface is not excluded. It is recommended to carry out a further cut-off date measurement in the hydrological summer season (01/05/2018 and 31/10/2018). No unambiguous and stable groundwater level up to a drilling depth of 20 m was found in drillings F1, F2, F4, F8 on the ridge of the site.

The stratified water encountered shows an agricultural influence in the levels F3, F6, F7 due to the increased content of nitrate, nitrite and ammonium. Similarly, in the levels F3, F6, indications of iron and mange in the water resulting from chemical soil weathering were found. Due to its high carbonate content, the water can be classified as "hard" at all levels. Traces of heavy metals were detected in the water from level F6, which, like the findings from the upper soil sampling with increased tar content, indicate a local embankment or pavement consolidation.

In general, no groundwater situation was encountered that could influence the construction project. With regard to possible groundwater use, the horizons of the upper shell limestone (mo2) would have to be explored from a depth of approx. 50 m (see Section 4: Geological risks and geopotentials).

13. Surface water

Investigation of surface water in the marginal streams and the Attert will take place in spring 2018, but no data are available at present.

Part 4: Geopotentials and geological risks

14. Geopotentials

The following positive site characteristics were demonstrated during the investigation:

14.1 Founding situation

The investigation revealed a relatively small surface course with a thickness of between 1 m and 3 m up to the solid rock (annexe 6.5).
For foundation, all types of foundations are also possible with high base stresses and can be carried out with conventional construction equipment.

Up to a depth of a few meters in the area of the construction sites, this does not include the inflow of relevant quantities of layered water, which requires additional insulation or sealing of the buildings.

The surface water flow is to be led away in a controlled manner through trenches and drains.
Due to the slope of the terrain and the valley cuts in the west and east of the site, controlled drainage of surface water is possible directly and via the natural slope.

14.2 Usable groundwater and surface water

From a depth of approx. 50 m the water-bearing dolomite banks of the upper shell limestone (mo) are located, which can be used for private water supply after approval by the authorities. Due to its high calcium and hydrogen carbonate content, the raw water is hard and needs to be treated before it can be used for technical purposes.

After approval by the authorities, service water can be taken from Attert, which is approx. 150 m until 600 m away, and pumped to the site approx. 40 m until 60 m high.

14.3 Energy

Geothermal energy from the horizons of the Keuper and the Muschelkalk can be used on site via geothermal probes after approval by the authorities.

At the same time, it is possible to use solar energy on the western slope because of the hillside location to the west.

Due to its elevated location on a plateau, the potential use of wind energy is possible after the approval procedure has been completed.

15. Geographical risks

<u>No geological risks have been identified at the site, so that only the "locational disadvantages" are listed in this context, which can be corrected with minor additional measures.</u>

15.1 Terrain morphology

The total area is divided into a high plateau with valley areas to the west and east. In the valley area, softened soils of several meters in thickness occur, which lead to additional expenses when building loads are established. In these areas, it is recommended that ancillary buildings and auxiliary facilities such as surface water retention basins, traffic and parking areas, infrastructure buildings and leisure facilities be set up. The layout of annexe 9 shows a rough breakdown into production zone and zone for auxiliary equipment.

Due to the general slope of the terrain, a wedge-shaped integration of the buildings into the subsoil and a rearrangement of the excavated soil is necessary. This can be done for individual buildings or by creating a uniform ground level.
A renewed use of the soil for terrain modelling is possible without restriction. Technical use as a substructure, e.g. for the production of platforms, is limited and locally possible due to the predominantly fine-grained structure.

An example of the construction of a general terrain platform is attached as annexe 9. Due to the masses of soil produced in the course of the excavation, the embankment in the valley area is also depicted. For the construction of surface reinforcements such as traffic areas or for adjoining buildings, there are low requirements with regard to the density of the soil. In the case of a technical application for taking up building loads, the soil masses must be prepared by mixing with coarse stone masses or by soil consolidation. The backfilled and prepared soil masses must be secured on the valley side by supporting bulkheads or retaining walls.

15.2 Founding situation

High sulphate values were found in the potential foundation half space, which required classification into a 'weak to highly aggressive soil XA2' according to DIN 4030.
Overall, the concrete foundations have to be built with a cement that has a high sulphate resistance (HS) and is effective against lime-solving carbonic acid.

Drains must be laid at the lower edge of the base layers under the floor slabs to limit the accumulation of seepage water under the concrete slabs. This significantly restricts the theoretical possibility of the formation of spring pressures under heated rooms by evaporation of sulphate-containing leachate.

Munsbach, 19/03/2018	Fugro Eco Consult s.à r.l.
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