Ortograph from project area ©Maanmittauslaitos

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AFRY

Ground Investigation Report and Foundation Proposal

Author
Simo Luukkonen
Phone
+358 50 411 2044
E-mail
simo.luukkonen@afry.com

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Client
Downing LLP

Siuntio Solar

AFRY Finland Oy
Infrastructural services, Oulu
Elektroniikkatie 13
FI-90590 Oulu
Tel. +358 10 3311
E-mail: firstname.lastname@afry.com
www.afry.com

Simo Luukkonen

M.Sc. Senior Consultant

Report history

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Contents

Drawings

1 Introduction

AFRY Finland Oy was commissioned by Downing LLP to carry out a ground investigation for the proposed development of a new solar power plant in Siuntio, Finland. Project area is located approximately 8 kilometers north of the Siuntio municipality center.

The project area covers approximately 95 hectares in total.

Ground investigations were conducted in February-March 2025. Investigation points have been measured on site. Otherwise, laser scan data provided by National Land Survey of Finland is used as initial data for terrain level.

The report includes a ground investigation of the panel area and planned substation area provides foundation proposal for the planned solar panel and substation structures.

2 Fieldworks

Ground investigation points were programmed to cover whole project area. Different sub soil areas were considered as programming the investigation points. The distance between investigation points was approximately from 100 meters to 200 meters for the panel areas. Electric station area has been investigated with denser point grid with approximately 15 m distance between points.

For the panel field areas, following ground investigation has been made:

- Measuring the investigation points
- Static-dynamic tests on 41 investigation points
- Disturbed soil sampling on 12 investigation points
- Standpipes for groundwater table on 2 locations

Following laboratory test were conducted for soil samples:

- Visual inspection of the samples 35 pcs
- Determination of grain size distribution and water content 15 pcs

For the electric station area, following ground investigation consist of following geotechnical investigations:

- Measuring the investigation points
- Static-dynamic tests on 4 investigation points
- Disturbed soil sampling on 1 investigation point
- Standpipes for groundwater table on 1 location

Following laboratory test were conducted for soil samples:

- Visual inspection of the samples 4 pcs

Used coordination system is ETRS-TM35FIN, and height system is N2000.

3 Soil conditions in the project area

3.1 Overview

Project area is mainly clayey field area. Fields are currently used for agricultural purposes. Northernmost and southernmost parts of the area are currently not in agricultural use and

there is forest growing in those areas. Terrain is higher at these areas and subsoil is coarses on these hilly areas.

Based on soil data information provided by Geological Survey of Finland (GTK), vast majority of the area is classified as clayey area. There are till areas in the very northeastern corner and south where terrain is higher compared to fields. GTK's soil map is presented in Figure 1.

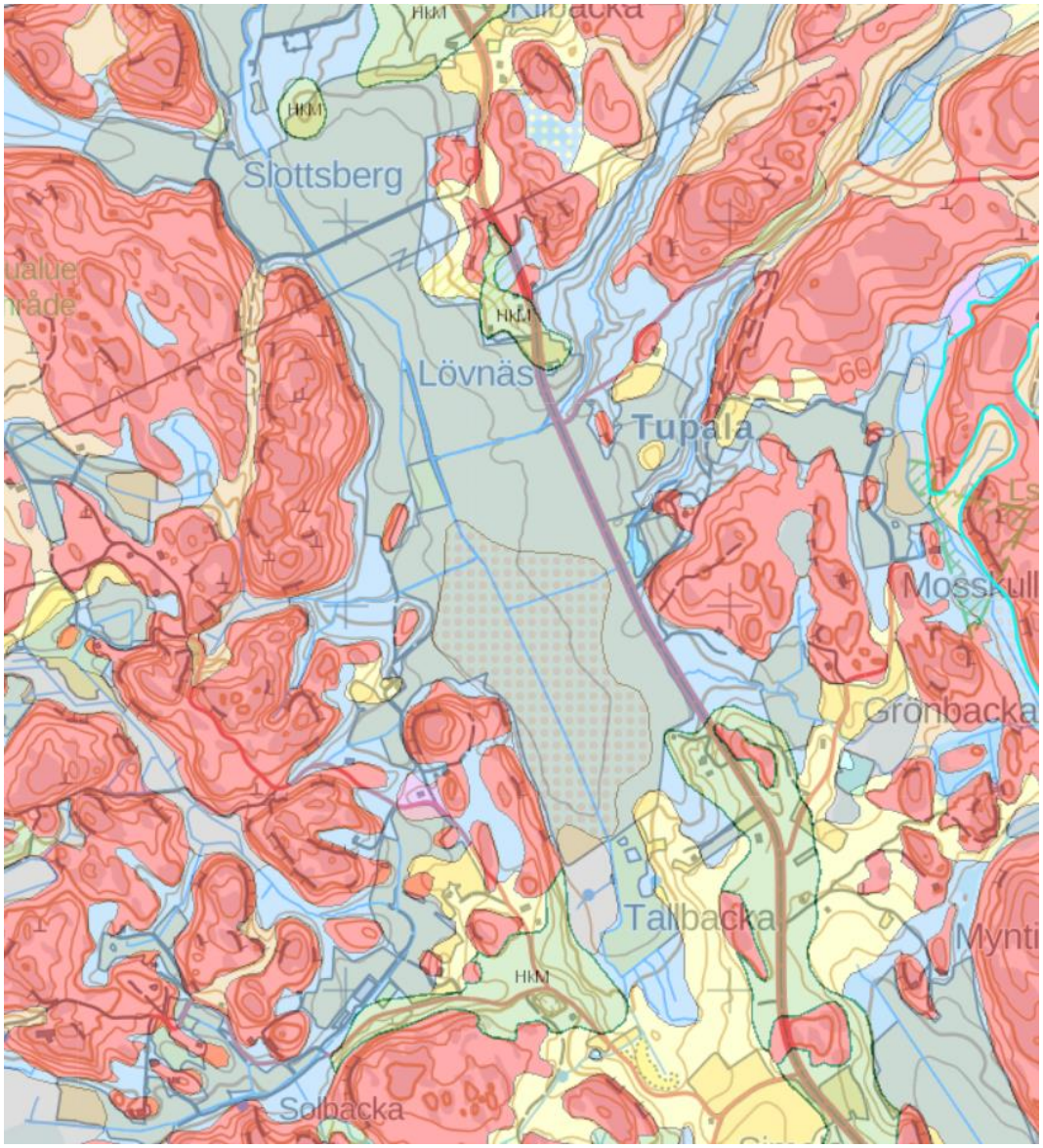

Figure 1. Subsoil types in the project area (source https://gtkdata.gtk.fi/maankamara/).

Generally, project area terrain is flat with couple of hills called Slottsberg located in the north and Tallbacka located in the south. Project area is surrounded by rocky hills and project area is a valley between those hills.

Field area ground level varies from level +30 to level +35. Terrain is sloping gently towards west. Hills rise to level +40 in the north and up to level +60 from sea level in the south. There are drainage diches on the fields, mostly in the east-west direction.

Bedrock level was not investigated but there are some outcrops marked on the map on top of the hills. Bedrock is very deep under the field areas.

Electric station is planned to locate in the northern part of the area where existing power line crosses the project area.

3.2 Soil conditions

From soil conditions perspective, area can be classified in two different types. One is clayey area on the fields and some forestry areas also. Hilly area in the north has also soft clay layer. Second area is tilly hill area in the south where terrain rises.

On clayey areas soil stratum is briefly following:

- Topsoil, vegetative soil approximately 0.5 m thick layer
- Dry crust clay approximately 1…1.5 m thick layer
- Soft clay, thickness varying from 5 to over 10 meters
    - Layer is thickest in the middle of the valley and getting thinner to the sides
- Loose silt and sand with varying thickness from 20 m to over 30 m
    - Layer is thickest in the middle of the valley and getting thinner to the sides
- Dense till layer

Majority of the static-dynamic tests have been terminated at the given length in the soft clay layer between the depth of 5 to 10 m from ground surface. Some the tests have been reached until dense till layer and tests have been terminated at the depth of 25…35 m from ground surface

On south-eastern hill area soil stratum is briefly following:

- Topsoil, vegetative soil approximately 0…0.3 m thick layer
- Loose to medium dense silt and sand approximately 0…5 m thick layer
- Dense till and bedrock

Static dynamic tests have been terminated at boulder or bedrock dense layer in the depth of 2…8 m

In the substation area, soil stratum is following:

- Topsoil, vegetative soil approximately 0…0.3 m thick layer
- Dry crust clay approximately 1…1.5 m thick layer
- Soft clay approximately 5 m thick layer
- Loose silt and sand clay approximately 7 m thick layer
- Dense till layer

All natural soils occurring at the area are considered as frost susceptible.

3.3 Ground water

Ground water has been measured on two standpipes from panel area and one standpipe from the substation area. Standpipe AF1_25 is located on the northern part of the area and ground water head has been measured to be at level +28,41 which is approximately 1.5m below ground level. Standpipe AF2_25 is located on the southern edge of Stormossen area

groundwater head has been measured to be at level +32,18 which is approximately 0.5m above ground level. Groundwater can be slightly pressured below the clay layers. In the substation area, groundwater head is measured to be at level +33.65 which is at the bottom of the clay layer in the depth of 6 m from surface. It is supposed that water head has not been risen after the installation. Water heads has been measured on 11.3.2025.

4 Foundation proposal

4.1 Solar panels

4.1.1 Piled foundation

Most of the area consist of thick clay layers. There solar panels can be founded on helical screw piles which will give better bearing capacity compared to driven or rammed steel profiles.

Screw piles will be screwed so that helix will reach below frost level which is 2.0 m in silty soil. Helical screw piles can be installed using rotary machine. Dimension of the pile and helix part shall be determined in later design phase. Uplift shall be taken into action when dimensioning the piles.

In the southeastern part where terrain rises and subsoil is glacial till, panels can be founded on driven/rammed steel profiles. Subsoil till can contain stones which can prevent the penetration of the screw piles deep enough. Foundation piles can be circular, square, C- or H-shaped profile. This pile type can be installed using driving or vibrating pile hammer

4.1.2 Founding on shallow foundations

Solar panels can alternatively be founded on shallow foundations if structures are allowed to have movements caused by frost heave or settlements. Frost protection of the foundations is not cost effective most likely.

On clayey area shallow foundations shall be founded on dry crust clay. Dry crust clay must not be broken. All fillings causing ground level to be elevated from existing level will cause settlement for the soft clay layers. Even relatively thin fill layers can cause settlement with magnitude of tens of millimeters.

On the southeastern part of the area, where subsoil is till, shallow foundations can be used.

Natural soil layers are frost susceptible. Foundations must be frost insulated or structural movements caused by frost heave shall be accepted.

Shallow foundations can be concrete beams on which solar panel frame will be constructed. Foundations need sufficient weight to prevent uplift caused by wind load. If shallow foundations are not frost protected, they are expected to undergo movements caused by soil freezing and frost heave. Magnitude of frost heave is difficult to estimate because there are many things that affect on the frost heave. Frost heave depends on cold content, soil frost susceptibility, soil water content and available water from beneath etc. All these factors change a lot and frost heave can vary a lot inside the project area.

Installation bed made of crushed rock shall be made below the concrete foundations.

4.2 Substations and transformers

4.2.1 Piled foundations

All structures sensitive to settlements (substation structures) are suggested being founded on driven concrete piles. Piles are end bearing piles reaching the dense till layer.

The geotechnical class is GL2, the consequence class is CC2. The piling work class is PTL2. Concrete piles and equipment must be CE marked and comply with the requirements of the Piling Guide PO-2016.

The geotechnical bearing capacity of driven concrete piles in the ultimate limit state in piling work class PTL2 is:

- for piles RTB-250-16 Rd,geo = 698 kN/pile

Estimated pile end level is presented in soil investigation section. Estimated pile length is approximately 15 m.

Piling platform made of crushed rock shall be made under the pield foundations. Thickness of the platform shall be designed according to used piling rig.

4.2.2 Shallow foundations

Structures that are not very sensitive to settlements, can be founded using shallow foundations. Smaller transformers can be founded on raft foundations founded on dry crust or in some places till. Possible settlements shall be taken into account for cable joints for example. Transformers and other similar structures shall be frost insulated. Bearing layer made of crushed rock shall be made under the shallow foundations.

4.3 Frost protection

According to Finnish frost protection guidebook *RIL 261-2013 "Routasuojaus"*, cold content at the Siuntio occurring once in 20 years is F_{20} = 30 000 Kh and once in 50 years F_{50} = 35 000 Kh. In subsoil consisting of silty soil, frost depth equivalent of F_{50} cold content is 2.0 m if insulating effect of snow is ignored.

Soils at the frost depth are frost susceptible. Structures are suggested to be protected against frost or foundations shall be reached below frost depth. If not so, it must be accepted that frost can cause heave to structures.

5 Road structures and drainage

5.1 Road structures

Design of the maintenance and service roads differs from the design of usual roadway. Service roads are seldomly used, and damages caused by frost heave will not have significant effect to traffic. Roads will not be asphalt covered and uneven surface caused by frost heave is easy to fix. Roads are dimensioned based on load carrying capacity. On soft areas, load carrying capacity can be improved using thicker subbase layer.

Road structures for maintenance roads at the moraine base are following:

- Leveling layer crushed rock #0/16 50 mm
- Base layer crushed rock #0/32…56 150 mm
- Subbase layer crushed rock #0/64 200 mm
- Filter cloth class N3

Total thickness	400 mm

Calculated bearing capacity of the structure is 80 MPa calculated on top of base layer. Bearing capacity can be improved by using geogrids or combigrids instead of filter cloth. Calculated frost heave is 150 mm if subsoil is silty soil in wet conditions.

All organic soil must be removed below the roads. Structure layer thickness is determined due to bearing capacity, frost heave is not limited at all. Road structures shall be drained to ensure sufficient load carrying capacity

5.2 Drainage

Currently area is mainly drained by field ditches leading to small stream or river called Kivikoskiån. This river must not be blocked. Drainage of the panel fields can be arranged using existing ditches or excavating similar ditches. Alternatively, under drains can be used if field ditches need to be filled. There are also some larger ditches or streams delivering waters to Kivikoskiån in east-west direction. These water routes must be kept open. There are no flood risk areas in the project area. Main water routes and flooding areas in the area is presented in Figure 2.

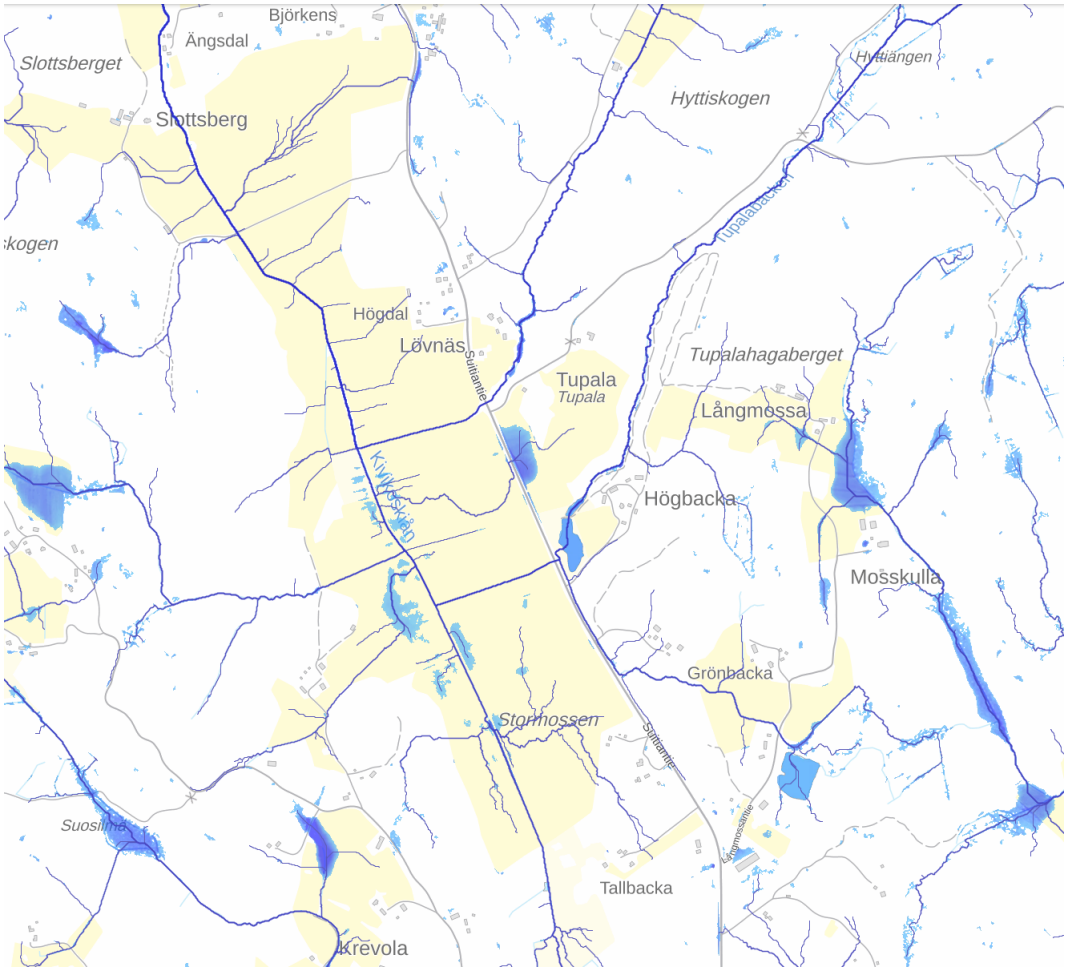

Figure 2. Main water routes and flood areas in the project area (source Scalgo Live).

6 Summary and further actions

In most of the area, earthworks required for the construction of a solar power plant are relatively minimal. In the forestry areas, construction requires cutting the trees and leveling the area. Hilly areas need more earthworks. In tilly areas, dense and stony till will most likely prevents using the screw piles. Instead, rammed steel profiles or shallow foundations can be used. If used shallow foundations, ballast weight shall be sufficient and panel frame structure must withstand possible movements caused by frost heave.

As the design and construction progresses, suitable foundation structures are suggested to be verified with test structures.