**GEO RESOURCES**

*GeoResource* Development Service Consultant Co.

# TOPOGRAPHIC AND GEOTECHNICAL FINAL REPORT FOR NECSOM NEW PLANT- GAROWE DISTRICT, NUGAL REGION, PUNTLAND STATE-SOMALIA

*GeoResource Techniques and tools*:
Integration of Remote sensing, GIS, and geophysical techniques to delineate Natural Resource.

*Client:* National Energy Corporation of Somalia (NECSOM)

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+252907828254, +252907704898

Info@geordc.com
grdsc2011@gmail.com
 https://geordc.com/

Islam Mohamed Street, Garowe, Nugal – Puntland, Somalia

*By:*
Omar Elim Barre: BSc Architecture – SHARQ ALNILE COLLEGE, Khartoum, Sudan.

Ismail Khalif Mohamud: BSc Geology –Neelain University, Khartoum, Sudan. Hydro-geophysicist.

Abdulfatah Abdullah
Environmntal Specialist, Bologna University, Italy

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# Executive summary:

The Geo-Resources Development Services Consultant Co., commissioned by the National Energy Corporation of Somalia (NECSOM), has conducted a topographic and geotechnical assessment of the proposed NEW NECSOM Solar Plant site in Garowe, Somalia. This report presents the findings of that assessment. The assessment was conducted to identify and characterize the physical features of the site, assess the suitability of the site for solar development, and identify and evaluate potential geotechnical hazards.

The topographic survey showed that the site is relatively flat, with a small hill from the west side. The elevation ranges from **569.815** meters to **549.108** meters. The soil conditions are also good, with a high bearing capacity and low permeability.

The geotechnical investigation revealed that the soil at the site is coarse sand, with no plasticity and no chemicals or minerals. The general appearance of the soil is hard, with rock starting at a **depth of 1 m** below the fine sand.

Based on the findings of the assessment, the site is suitable for the construction of a solar plant. The following recommendations are made:

- The solar panels could be installed on all flat areas of the site.

- A drainage system occurs naturally since the general slope will not allow water to stop within the plant zone.

- The construction foundation depth is recommended to 1.2 m in the flat area (most of plant and 0.4 on the top of hill it clears in the map (contour map).

- A perimeter fence should be installed around the solar plant to prevent unauthorized access.


Overall, the NECSOM Solar Plant site is a good location for the development of a solar plant. The site is relatively flat, with good soil conditions and a low risk of geotechnical hazards.

# 1 Introduction

## 1.1 Purpose of the Assessment

The purpose of a topographic and geotechnical assessment for a solar plant development project in Somalia is to:

- Identify and characterize the physical features of the site. This includes the topography, geology, soils, and groundwater conditions.

- Assess the suitability of the site for solar development. This includes evaluating the site's slope, aspect, solar radiation potential, and other factors that may impact the project's feasibility.

- Identify and evaluate potential geotechnical hazards. This includes hazards such as flooding, landslides, and liquefaction.

- Develop recommendations for mitigation measures and foundation design. This information is essential for ensuring the safe and reliable operation of the solar plant.

Overall, the purpose of the topographic and geotechnical assessment is to provide the information necessary to make informed decisions about the feasibility, design, and construction of the solar plant project.

## 1.2 Scope of the Assessment

The scope of the topographic and geotechnical assessment for a solar plant development project in Somalia will typically include the following:

Topographic Survey

- Site survey: This involves surveying the entire site to create a detailed topographic map of the area. The survey will include the following:
    - Establishing survey control points
    - Measuring the elevation of the ground at various points throughout the site
    - Identifying and mapping any natural or man-made features on the site
- Digital elevation model (DEM) of the site. The DEM can be used to generate contour maps, slope maps, and other topographic data.

Geotechnical Investigation
- Subsurface exploration: This involves drilling boreholes into the ground to collect soil samples. The soil samples will be tested in a laboratory to determine their engineering properties.

- Laboratory testing: The laboratory testing will include the following:
  - Grain size analysis
  - Atterberg limits testing
  - Determination of flakiness index
  - Specific gravity and water absorption
- Geotechnical characterization: The geotechnical characterization will involve analyzing the soil test results to determine the geotechnical properties of the site. This information will be used to assess the suitability of the site for solar development and to develop recommendations for foundation design and other geotechnical engineering considerations.

## 1.3 Site Location and Description

Garowe is the capital of Nugal region and administrative capital of Puntland state in northeastern Somalia. The geographical coordinates of the town are 48.483056 ° East Longitude and 8.406389 ° North Latitude with an average elevation of 465 m. Garowe is traversed by a 750 km north-south highway. It connects major cities in the northern part of the country, such as Bossaso and Galkayo with towns in the south.
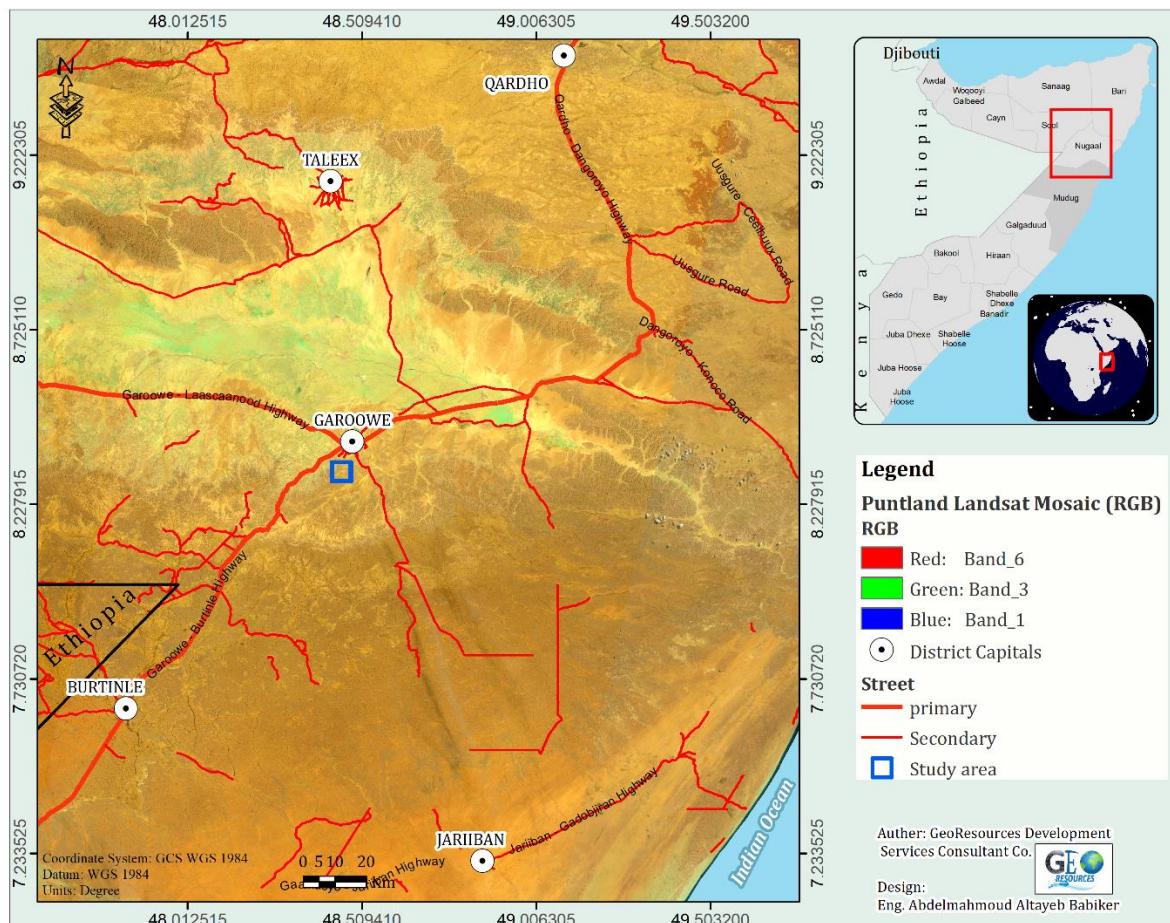


*Figure 1: location Map*

# 2 Topographic Survey

Topographic Survey of NECSOM Solar Plant is a survey that is carried out to investigate the topography of the land where the solar plant is to be built. The survey will help to determine the best location for the solar plant, as well as the best way to design the plant.

## 2.1 Survey Methodology

Topographic survey methodology is the process of collecting and processing data to create a map of the Earth's surface. The map shows the elevation and position of natural and man-made features. During this assignment the following steps were typically involved:

1. Planning: The first step is to plan the survey, which includes determining the area to be surveyed, the level of detail required, and the desired accuracy.

2. Data collection: Data collection can be done using a variety of methods, including:

   o Ground surveying: This involves using instruments such as RTK (Real Time Kinematic) and GNSS receivers to measure the distance and elevation of points on the ground to create a digital elevation model (DEM).

   o Remote sensing: This involves using satellite imagery and other remote sensing data to collect information about the topographic feature and existing structure.

3. Data processing: Once the data has been collected, it needs to be processed to create a map. This involves correcting the data for errors, such as atmospheric refraction and instrument errors. It also involves generating contour lines, which are lines that connect points of equal elevation.

4. Map preparation: The final step is to prepare the map for delivery to the client. This may involve adding features such as labels, legends, and scale bars.

To conduct a topographic survey using **RTK,** the following steps are typically followed:

1. Establish a base station. This can be done by setting up the base receiver at a known location, such as a control point or benchmark.

2. Collect data with the rover station. The rover station is carried around the survey area, taking measurements at regular intervals. The data collector will display the real-time coordinates of the rover station, which can be used to guide the surveyor to the desired locations.

3. Post-process the data. Once the data collection is complete, the data is post-processed to remove any errors and to adjust the coordinates to a desired coordinate system.

## 2.2  Topographic Features

The topographic shows a small area of land with a relatively flat elevation. The elevation ranges from 569.815 meters to 549.108 meters, with a gradual slope from west t. The map also shows several  features, including roads, building. The contour lines on the map are spaced at 2.5-meter intervals, which means that each contour line represents a change in elevation of 0.5 meters. Contour lines indicate elevation, with closer lines representing steeper terrain. The map shows a central elevated area with closely spaced lines, surrounded by gentler slopes. The boundary of the site is marked with blue and green lines and coordinate points. Scaled at 1:11,500, meaning 1 unit on the map equals 11,500 units on the ground.

- The west side of the map is slightly higher in elevation than the east side. This can be seen by the fact that the contour lines are farther apart on the west side of the map.

- The slope is from west to east, and the pond is in the lowest part of the area. This can be seen by the fact that the contour lines bulge outward around the flow direction and pond.

- The man-made features on the map, such as the roads, buildings, are all located on the higher ground. This is because it is easier to build on higher ground, and it is also less likely to be flooded.
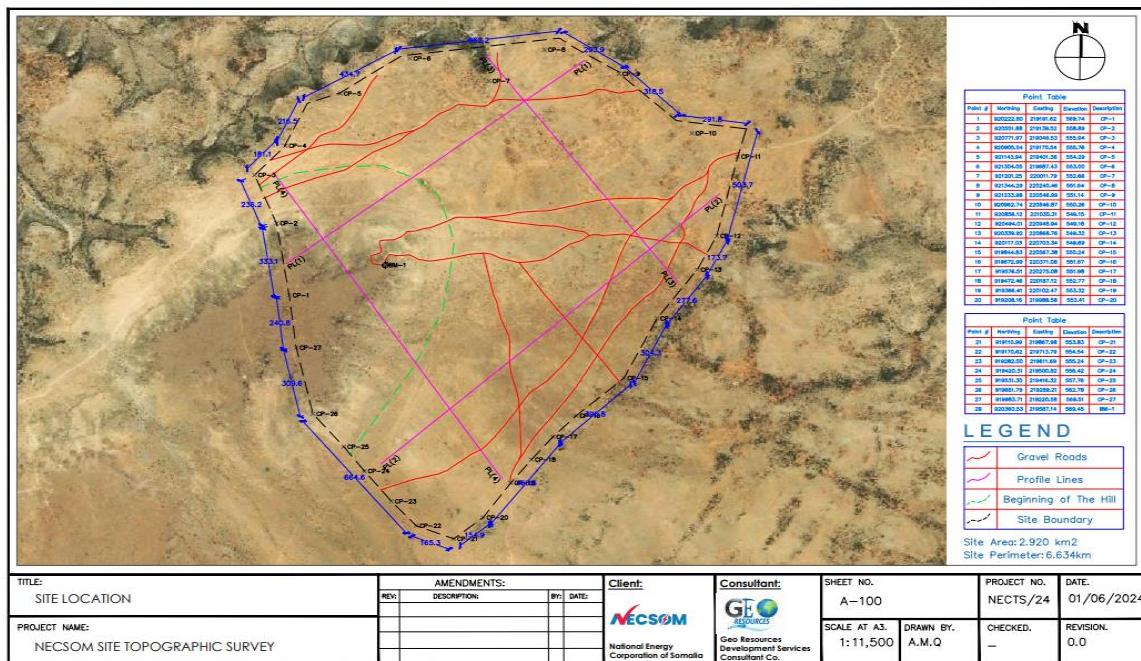


*Figure 2: Site Plan*
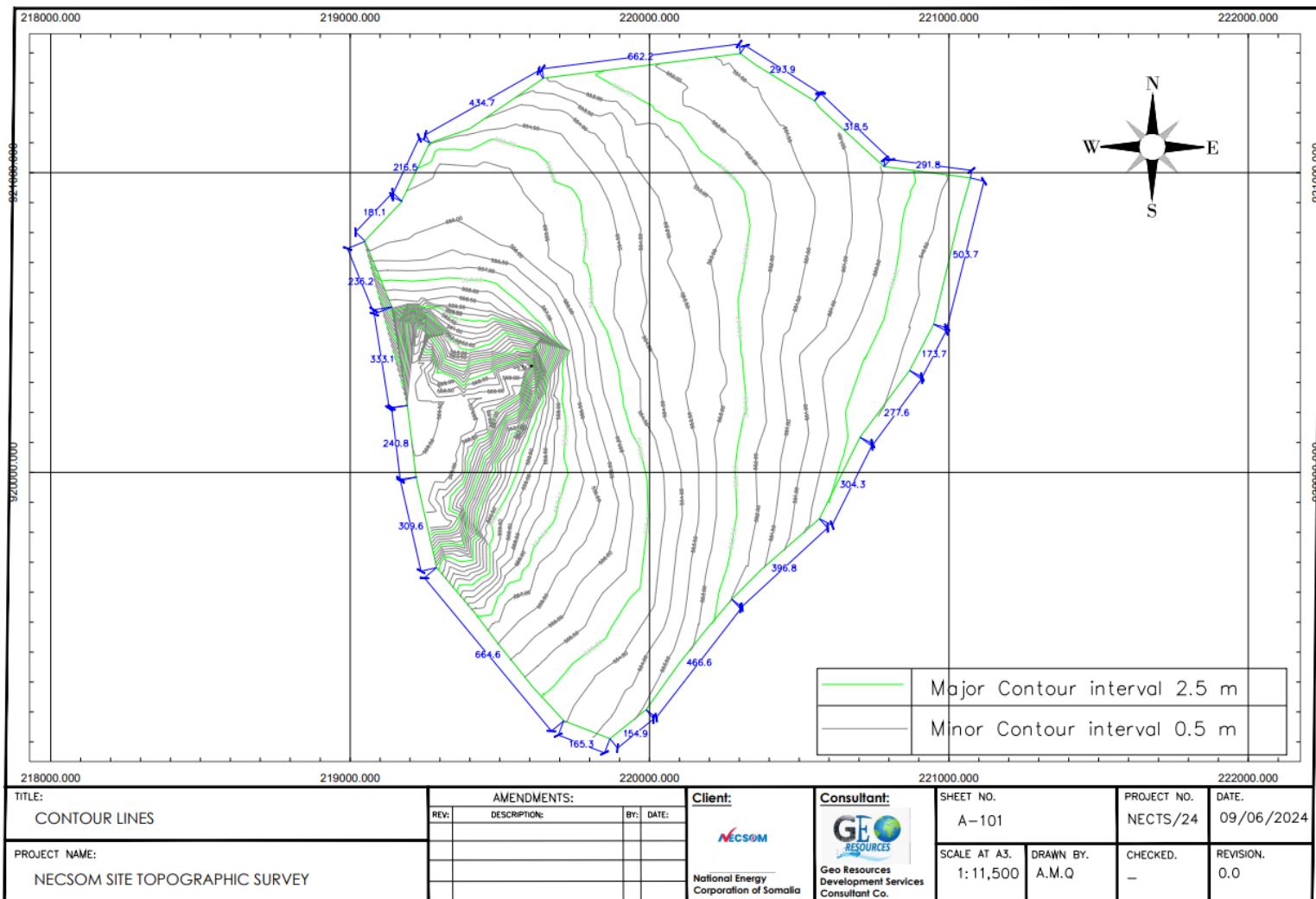
*Figure 3:Contour map (NECSOM PLANT)*

*Figure 4: 3D topo Map*

# 3 Geotechnical Investigation

This chapter presents the results of the geotechnical fieldwork and laboratory testing conducted for the proposed NECSOM solar plant development site in Garowe. Geotechnical fieldwork collects data about the subsurface conditions at a site. This data is used to assess the site's suitability for development and to design foundations and other structures. The laboratory testing included grain size analysis, Atterberg limits testing, Determination of flakiness index testing and Specific gravity and water absorption of aggregate. The results of the geotechnical fieldwork and laboratory testing were used to characterize the geotechnical properties of the site and to assess the suitability of the site for solar development.

## 3.1 Fieldwork and sampling

The fieldwork was conducted on 06/01/2024 and consisted of the following.
- Material Sampling.
- Particle Size Distribution of Soil.
- Atterberg Limit.
- Determination of Flakiness index.
- Specific Gravity and Water Absorption of Aggregate

**a. Material Sampling:**



*Figure 5: Soil Samplin*

The side was selected randomly from 10 trail pits as you can see in the image below.

*Table 1:Soil Sampling information*

| Trial Pit No. | Coordinates | | Sample depth (m) | Sample collected for lab work |
|---|---|---|---|---|
| | **Northing** | **Easting** | | |
| 1. | 8.317969 | 48.454318 | 1.5 | Sample# (TP-1) |
| 2. | 8.319900 | 48.449965 | 1.5 | Sample# (TP-2) |
| 3. | 8.322752 | 48.467316 | 1.5 | Sample# (TP-3) |
| 4. | 8.300476 | 48.453540 | 1.5 | Sample# (TP-4) |
| 5. | 8.314015 | 48.457037 | 1.5 | Sample# (TP-5) |

## 3.2  Laboratory Testing

### 3.2.1  Particle Size Distribution of Soil:

Particle size distribution (PSD) is an important engineering property of soils that can be used in a wide range of engineering applications, such as assessing the geotechnical properties of soils.

Two key parameters in PSD analysis are the uniformity coefficient (Cu) and the coefficient of curvature (Cc).

The uniformity coefficient (Cu) is a measure of the range of particle sizes in a soil sample.

It is calculated as: $Cu = \frac{D_{60}}{D_{10}}$ where $D_{60}$ and $D_{10}$ are the particle diameters at 60% and 10% passing, respectively.

The coefficient of curvature (Cc) provides information about the shape of the particle size distribution curve and is calculated as: $Cc = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ where $D_{30}$ is the particle diameter at 30% passing.
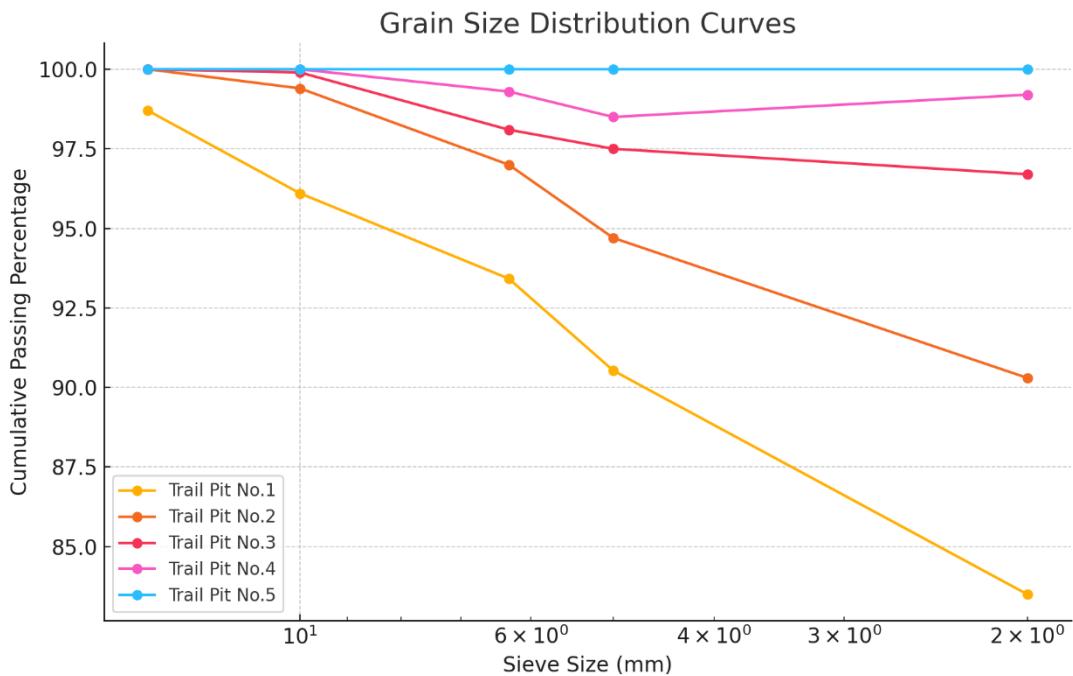
*Figure 6: Grain size distribution size curves*

The graph below shows the grain size distribution curves for five different trail pits:

Trail Pit No. 1: Shows a relatively wide range of particle sizes with cumulative passing percentages decreasing significantly as the sieve size decreases, indicating a well-graded soil.

Trail Pit No. 2: Similar to Trail Pit No. 1, but with slightly higher passing percentages, also indicating well-graded soil.

Trail Pit No. 3: Shows a very high cumulative passing percentage, close to 100%, indicating uniform soil with fewer particle size variations.

Trail Pit No. 4: Displays a high percentage passing through all sieve sizes, similar to Trail Pit No. 3, but with a slight decrease at smaller sieve sizes.

Trail Pit No. 5: Consistently shows 100% passing, indicating highly uniform soil.

These curves indicate that the soil samples are generally well-graded with a wide range of particle sizes. The uniformity coefficient (Cu) for the samples varies, but in well-graded soils, Cu values are typically higher, indicating a good range of particle sizes. For example, a sample with a Cu of 6 and a Cc of 1.5 would be considered well-graded.

Additionally, the curves suggest that some soil samples may have a high void ratio. A higher void ratio, such as 0.8, indicates that the soil is loose and may require more compaction to achieve the desired bearing capacity.

### 3.2.2 Atterberg Limit:
This test is carried out to establish the liquid limit plastic limit and linear shrinkage of the soil material.

This was carried on samples obtained from the trail samples. Liquid limit is the empirically established

moisture content at which a soil passes from the liquid stage to plastic state while plastic limit is the empirical moisture content at which a soil becomes too dry to be plastic. The difference between the two gives the Plasticity Index. The trail samples have no Plasticity as they are (coarse Sand). Coarse sand usually doesn't have plasticity according to the AASHTO soil classification AASHTO M145.

### 3.2.3    Determination of Flakiness index:

The percentage by mass of stones in an aggregate having an ALD of less than 0.6 times their average dimension. Flaky aggregates tend to produce seals with less voids due to their tendency to pack more tightly than cubical aggregates, consequently flaky particles require less binder. Five different sizes of aggregate were tested (37.7, 28.0, 20.0, 14.0, 10.0) mm as you can see the summary of results below.

| Aggregate Sizes (mm) | Flakiness Index % |
|---|---|
| 37.5 | 43 |
| 28.0 | 38 |
| 20.0 | 28 |
| 14.0 | 39 |
| 10.0 | 51 |

### 3.2.4    Specific Gravity and Water Absorption of Aggregate:

Specific gravity Is the ratio of the mass or weight in air of a unit volume of a material to the mass of the same volume of water at stated temperature values are dimensionless. Aggregates having low specific gravity is generally weaker than those with high specific gravity. Water absorption the increase in the mass of aggregate due to water in the pores of the material, but not including water adhering to the outside surface of the particles, expressed as a percentage of the dry mass.

Aggregates have more water absorption is weaker than those have less water absorption. Five different sizes of aggregate were tested (37.7, 28.0, 20.0, 14.0, 10.0) mm as you can see the summary of results below:

| Aggregate Sizes (mm) | Specific Gravity | Water Absorption % |
|---|---|---|
| 37.5 | 2.68 | 0.51 |
| 28.0 | 2.51 | 0.78 |
| 20.0 | 2.48 | 0.60 |
| 14.0 | 2.67 | 0.75 |
| 10.0 | 2.39 | 0.86 |

## 3.3  Soil and Rock Conditions

Based on the findings of the investigations, the trail samples are identical type of soil (coarse sand) they have no plasticity and also have no chemicals and minerals that came off.  The general appearance of the soil is hard and continues rock starting at depth of `100 cm below the fine sand. Therefore, we are suggesting the following estimate of the allowable soil bearing capacity for use of a very shallow foundation design. The most important finding of this report is that the nature of the land is hard rock.

| Recommended Foundation Depth with Screed | Layer Type | CBR (%) | Estimated Allowable Bearing Capacity (KN/m2) |
|---|---|---|---|
| 1 meter (1O0 cm) | Rocky and compacted coarse sand/gravel soil | 100 | (above 5,000) kpa |

## 3.4  Groundwater Conditions

Groundwater aquifers in the study area are karstic type controlled by structures such as fault and fracture. The aquifers seemed to be encountered in Karkar Formation, which consist of marls and shales with intercalations of water bearing limestone, chert, marls, and siltstones to depths of approximately 400m below ground level.

Based on that information the water table is very deep with absence of shallow aquifer and the water table of the area is about 20m.

## 3.5  Conclusion

The comprehensive topographic and geotechnical assessment conducted for the NECSOM Solar Plant in Garowe, Somalia, provides an in-depth analysis of the site's suitability for solar development. The topographic survey reveals a relatively flat terrain with a gradual slope from west to east, ideal for solar plant construction. Key features such as existing roads offer potential infrastructural advantages. The natural elements like a stream and a small pond did not occur.

Geotechnically, the site predominantly consists of well-graded coarse sand with high void ratios, indicating loose soil conditions at the topsoil. The soil's lack of plasticity, as per the AASHTO soil classification, and the presence of hard rock substrates at shallow depths, suggest strong foundational support for construction. The site's deep-water table and the absence of a shallow aquifer further contribute to its suitability, reducing the risk of groundwater-related issues.

# 4  Recommendations.

The topographic and geotechnical assessment of the NECSOM Solar Plant site has shown that the site is suitable for the construction of a solar plant as well as wind turbines. The site is relatively flat, with a steep slope from a small hill in the west part. The soil conditions are also good, with a high bearing capacity and low permeability.

Based on the findings of the assessment, the following recommendations are made:

- The solar panels could be installed on all flat areas of the site.

- A drainage system occurs naturally since the general slope will not allow water to stop within the plant zone.

- The construction foundation depth is recommended to 1.2 m in the flat area (most of plant and 0.4 on the top of hill it clears in the map (contour map).

- A perimeter fence should be installed around the solar plant to prevent unauthorized access.

# 5 Appendices

## 5.1 Appendix A: Topographic Raw Data

| Nu | Northing | Easting | Elevation | Description |
|----|----------|---------|-----------|-------------|
| | Necsom Site Surveying Data | | | |
| 1 | 920360.529 | 219587.143 | 569.449 | BM-1 |
| 2 | 920362.259 | 219581.554 | 569.353 | EGL |
| 3 | 920332.652 | 219499.921 | 569.367 | EGL |
| 4 | 920222.599 | 219191.867 | 569.679 | EGL |
| 5 | 920222.805 | 219191.617 | 569.743 | POLE-1 |
| 6 | 920222.586 | 219190.615 | 569.622 | SBM |
| 7 | 920349.059 | 219205.213 | 569.769 | EGL |
| 8 | 920551.883 | 219139.524 | 558.894 | POLE-2 |
| 9 | 920551.579 | 219138.871 | 558.848 | SBM |
| 10 | 920771.974 | 219049.529 | 555.939 | POLE-3 |
| 11 | 920771.208 | 219046.335 | 555.846 | SBM |
| 12 | 920771.477 | 219046.335 | 555.835 | RD |
| 13 | 920775.886 | 219044.914 | 555.745 | RD |
| 14 | 920905.538 | 219175.544 | 555.765 | POLE-4 |
| 15 | 920907.587 | 219173.767 | 555.71 | SBM |
| 16 | 921143.935 | 219401.381 | 554.288 | POLE-5 |
| 17 | 921146.725 | 219400.232 | 554.238 | SBM |
| 18 | 921099.463 | 219266.239 | 554.435 | SBM |
| 19 | 921313.282 | 219644.681 | 553.064 | SBM |
| 20 | 921314.423 | 219646.173 | 553.065 | RD |
| 21 | 921316.107 | 219653.35 | 553.025 | RD |
| 22 | 921304.047 | 219687.434 | 553.004 | POLE-6 |
| 23 | 921307.155 | 219689 | 552.832 | SBM |
| 24 | 921201.252 | 220011.787 | 552.658 | POLE-7 |
| 25 | 921210.445 | 220007.646 | 552.55 | SBM |
| 26 | 921344.292 | 220240.461 | 551.637 | POLE-8 |
| 27 | 921351.903 | 220236.669 | 551.538 | SBM |
| 28 | 921396.876 | 220303.248 | 551.29 | SBM |
| 29 | 921233.978 | 220546.988 | 551.135 | POLE-9 |
| 30 | 921239.552 | 220551.445 | 551.099 | SBM |
| 31 | 920962.741 | 220846.873 | 550.255 | POLE-10 |
| 32 | 920965.886 | 220849.752 | 550.178 | SBM |
| 33 | 920982.43 | 221072.018 | 549.141 | SBM |
| 34 | 920856.124 | 221035.308 | 549.152 | POLE-11 |
| 35 | 920855.035 | 221037.129 | 549.108 | SBM |
| 36 | 920494.012 | 220948.939 | 549.183 | POLE-12 |

| 37 | 920492.496 | 220950.125 | 549.233 | SBM |
|---|---|---|---|---|
| 38 | 920339.917 | 220868.763 | 549.318 | POLE-13 |
| 39 | 920336.359 | 220874.745 | 549.292 | SBM |
| 40 | 920117.029 | 220703.343 | 549.686 | POLE-14 |
| 41 | 920111.484 | 220708.217 | 549.603 | SBM |
| 42 | 919844.834 | 220567.381 | 550.243 | POLE-15 |
| 43 | 919842.032 | 220569.718 | 550.107 | SBM |
| 44 | 919672.990 | 220371.078 | 551.671 | POLE-16 |
| 45 | 919671.014 | 220372.029 | 551.581 | SBM |
| 46 | 919576.510 | 220275.079 | 551.977 | POLE-17 |
| 47 | 919575.425 | 220276.909 | 551.932 | SBM |
| 48 | 919472.458 | 220187.117 | 552.770 | POLE-18 |
| 49 | 919469.112 | 220188.401 | 552.684 | SBM |
| 50 | 919366.407 | 220102.472 | 553.315 | POLE-19 |
| 51 | 919365.942 | 220103.757 | 553.183 | SBM |
| 52 | 919208.160 | 219988.584 | 553.407 | POLE-20 |
| 53 | 919205.708 | 219990.072 | 553.388 | SBM |
| 54 | 919110.993 | 219867.98 | 553.833 | POLE-21 |
| 55 | 919108.124 | 219869.573 | 553.723 | SBM |
| 56 | 919119.684 | 219794.068 | 554.066 | SBM |
| 57 | 919170.622 | 219713.791 | 554.540 | POLE-22 |
| 58 | 919170.242 | 219711.301 | 554.509 | SBM |
| 59 | 919282.000 | 219611.688 | 555.243 | POLE-23 |
| 60 | 919280.524 | 219610.209 | 555.207 | SBM |
| 61 | 919420.307 | 219500.816 | 556.422 | POLE-24 |
| 62 | 919417.030 | 219499.469 | 556.374 | SBM |
| 63 | 919531.299 | 219416.324 | 557.756 | POLE-25 |
| 64 | 919529.968 | 219413.801 | 557.658 | SBM |
| 65 | 919681.786 | 219289.208 | 562.783 | POLE-26 |
| 66 | 919680.666 | 219286.841 | 562.788 | SBM |
| 67 | 919983.706 | 219220.582 | 569.506 | POLE-27 |
| 68 | 919985.449 | 219220.174 | 569.391 | SBM |
| 69 | 920548.248 | 219142.875 | 558.982 | EGL |
| 70 | 920564.876 | 219224.54 | 558.578 | EGL |
| 71 | 920554.249 | 219339.411 | 559.041 | EGL |
| 72 | 920544.23 | 219464.734 | 558.786 | EGL |
| 73 | 920502.375 | 219633.875 | 557.446 | EGL |
| 74 | 920404.187 | 219738.95 | 556.535 | EGL |
| 75 | 920262.067 | 219871.023 | 555.265 | EGL |
| 76 | 920104.879 | 220008.134 | 554.605 | EGL |
| 77 | 919999.617 | 220101.66 | 554.03 | EGL |

| | | | | |
|---|---|---|---|---|
| 78 | 919855.904 | 220228.714 | 552.956 | EGL |
| 79 | 919735.37 | 220323.868 | 552.085 | EGL |
| 80 | 919678.512 | 220372.351 | 551.594 | EGL |
| 81 | 919763.075 | 220443.677 | 551.172 | EGL |
| 82 | 919866.983 | 220384.175 | 551.827 | EGL |
| 83 | 920052.632 | 220266.015 | 552.64 | EGL |
| 84 | 920268.377 | 220108.069 | 553.556 | EGL |
| 85 | 920384.279 | 220035.207 | 553.917 | EGL |
| 86 | 920477.659 | 219947.995 | 554.089 | EGL |
| 87 | 920553.021 | 219838.801 | 554.725 | EGL |
| 88 | 920626.191 | 219687.224 | 556.02 | EGL |
| 89 | 920656.412 | 219546.725 | 556.767 | EGL |
| 90 | 920702.588 | 219339.445 | 556.695 | EGL |
| 91 | 920725.105 | 219174.551 | 556.195 | EGL |
| 92 | 920738.89 | 219068.758 | 556.003 | EGL |
| 93 | 920736.934 | 219061.522 | 556.016 | EGL |
| 94 | 920785.34 | 219042.369 | 555.572 | SBM |
| 95 | 920799.832 | 219084.039 | 555.834 | EGL |
| 96 | 920834.373 | 219215.182 | 555.799 | EGL |
| 97 | 920873.865 | 219351.412 | 555.843 | EGL |
| 98 | 920916.512 | 219532.555 | 555.724 | EGL |
| 99 | 920969.127 | 219683.27 | 555.001 | EGL |
| 100 | 921034.65 | 219878.432 | 554.019 | EGL |
| 101 | 921042.378 | 219922.807 | 553.546 | EGL |
| 102 | 921073.262 | 220098.603 | 553.028 | EGL |
| 103 | 921091.671 | 220167.386 | 552.431 | EGL |
| 104 | 921124.342 | 220270.501 | 551.987 | EGL |
| 105 | 921178.286 | 220436.296 | 551.464 | EGL |
| 106 | 921223.857 | 220540.777 | 551.127 | EGL |
| 107 | 921230.078 | 220550.668 | 551.107 | EGL |
| 108 | 921196.372 | 220581.835 | 551.075 | EGL |
| 109 | 921179.13 | 220511.753 | 551.283 | EGL |
| 110 | 921171.897 | 220451.942 | 551.471 | EGL |
| 111 | 921161.454 | 220387.298 | 551.617 | EGL |
| 112 | 921135.966 | 220291.16 | 551.913 | EGL |
| 113 | 921111.254 | 220061.308 | 553.034 | EGL |
| 114 | 921039.468 | 219762.441 | 554.575 | EGL |
| 115 | 921011.473 | 219645.634 | 555.086 | EGL |
| 116 | 920989.571 | 219506.361 | 555.672 | EGL |
| 117 | 920966.124 | 219380.026 | 555.871 | EGL |
| 118 | 920936.433 | 219269.349 | 555.788 | EGL |

| 119 | 920908.893 | 219181.606 | 555.723 | EGL |
|-----|------------|------------|---------|-----|
| 120 | 920952.558 | 219277.574 | 555.755 | EGL |
| 121 | 920992.95 | 219431.181 | 555.765 | EGL |
| 122 | 921031.792 | 219559.266 | 555.347 | EGL |
| 123 | 921076.627 | 219692.529 | 554.8 | EGL |
| 124 | 921117.996 | 219801.461 | 554.127 | EGL |
| 125 | 921153.678 | 219901.988 | 553.548 | EGL |
| 126 | 921177.77 | 219958.71 | 552.916 | EGL |
| 127 | 921202.096 | 220011.076 | 552.602 | EGL |
| 128 | 921201.212 | 220066.337 | 552.254 | EGL |
| 129 | 921241.482 | 220148.307 | 551.818 | EGL |
| 130 | 921282.111 | 220225.192 | 551.736 | EGL |
| 131 | 921321.045 | 220295.329 | 551.516 | EGL |
| 132 | 921351.69 | 220345.208 | 551.34 | EGL |
| 133 | 921358.733 | 220355.359 | 551.308 | SBM |
| 134 | 921309.024 | 220401.489 | 551.443 | EGL |
| 135 | 921309.571 | 220404.289 | 551.451 | SBM |
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| 757 | 920061.4987 | 219373.8209 | 568.648 | EGL |
| 758 | 920068.5638 | 219404.4668 | 567.579 | EGL |
| 759 | 920074.8439 | 219441.399 | 566.0172 | EGL |
| 760 | 920081.909 | 219469.6876 | 565.4082 | EGL |
| 761 | 920093.6842 | 219508.9772 | 563.4161 | EGL |
| 762 | 920107.0294 | 219549.8384 | 561.703 | EGL |
| 763 | 920118.8046 | 219588.3422 | 560.2139 | EGL |
| 764 | 920135.2899 | 219626.846 | 559.4313 | EGL |
| 765 | 920147.8501 | 219668.493 | 558.4584 | EGL |
| 766 | 920147.0651 | 219718.7837 | 557.5362 | EGL |
| 767 | 920145.495 | 219764.3596 | 556.8031 | EGL |
| 768 | 920143.14 | 219823.294 | 556.095 | EGL |
| 769 | 920204.4628 | 219854.4836 | 555.637 | EGL |
| 770 | 920213.1942 | 219810.7831 | 556.0449 | EGL |
| 771 | 920222.7194 | 219766.2881 | 556.5202 | EGL |
| 772 | 920220.3381 | 219712.2585 | 557.4905 | EGL |
| 773 | 920218.7506 | 219656.6397 | 559.1946 | EGL |
| 774 | 920213.1942 | 219620.0903 | 560.4745 | EGL |

| | | | | |
|---|---|---|---|---|
| 775 | 920209.2254 | 219595.4591 | 562.6012 | EGL |
| 776 | 920202.8753 | 219561.2933 | 565.2214 | EGL |
| 777 | 920196.5252 | 219521.5656 | 566.0172 | EGL |
| 778 | 920189.6339 | 219481.4892 | 567.4049 | EGL |
| 779 | 920182.531 | 219445.9394 | 568.7328 | EGL |
| 780 | 920176.4428 | 219401.756 | 569.2841 | EGL |
| 781 | 920170.8619 | 219368.7455 | 569.3818 | EGL |
| 782 | 920168.4056 | 219335.6893 | 569.4039 | EGL |
| 783 | 920165.1593 | 219289.3842 | 569.5073 | EGL |
| 784 | 920162.7246 | 219256.8894 | 569.5535 | EGL |
| 785 | 920160.29 | 219229.2687 | 569.5873 | EGL |
| 786 | 920196.8104 | 219220.3327 | 569.6188 | EGL |
| 787 | 920195.1873 | 219270.6996 | 569.5476 | EGL |
| 788 | 920202.4913 | 219325.9409 | 569.4522 | EGL |
| 789 | 920204.926 | 219381.1821 | 569.4513 | EGL |
| 790 | 920213.0417 | 219446.9841 | 568.3736 | EGL |
| 791 | 920220.3458 | 219486.7903 | 568.3329 | EGL |
| 792 | 920224.4036 | 219530.6583 | 567.2008 | EGL |
| 793 | 920232.3984 | 219568.8389 | 566.1994 | EGL |
| 794 | 920237.5001 | 219598.4582 | 563.2651 | EGL |
| 795 | 920242.6968 | 219632.4126 | 560.6367 | EGL |
| 796 | 920243.2098 | 219668.8723 | 558.8155 | EGL |
| 797 | 920243.7228 | 219706.8726 | 557.5174 | EGL |
| 798 | 920244.7488 | 219753.6027 | 556.6702 | EGL |
| 799 | 920241.9878 | 219380.1931 | 569.4796 | EGL |
| 800 | 920188.4876 | 219377.568 | 569.4184 | EGL |
| 801 | 920181.6689 | 219268.8863 | 569.5447 | EGL |
| 802 | 920231.4976 | 219272.5615 | 569.5528 | EGL |
| 803 | 920135.5119 | 219270.9864 | 569.5203 | EGL |
| 804 | 920438.625 | 219319.6107 | 563.058 | EGL |
| 805 | 920462.3794 | 219337.4441 | 561.5173 | EGL |
| 806 | 920486.9821 | 219357.8253 | 560.6777 | EGL |
| 807 | 920509.8881 | 219376.5079 | 560.0012 | EGL |
| 808 | 920536.1876 | 219393.4922 | 559.2747 | EGL |
| 809 | 920560.7904 | 219412.1749 | 558.6975 | EGL |
| 810 | 920585.3932 | 219433.4052 | 558.2425 | EGL |
| 811 | 920609.1475 | 219456.334 | 557.9303 | EGL |
| 812 | 920624.4182 | 219480.1119 | 557.6136 | EGL |
| 813 | 920421.6576 | 219377.3572 | 562.2565 | EGL |
| 814 | 920436.0799 | 219392.643 | 561.7828 | EGL |
| 815 | 920453.8957 | 219411.3257 | 561.2617 | EGL |

| 816 | 920471.7115 | 219432.556 | 560.7518 | EGL |
| 817 | 920489.5272 | 219454.6355 | 560.4082 | EGL |
| 818 | 920510.7365 | 219478.4135 | 560.162 | EGL |
| 819 | 920521.9967 | 219253.4817 | 563.2068 | EGL |
| 820 | 920542.3527 | 219267.0659 | 560.8358 | EGL |
| 821 | 920562.3412 | 219282.7083 | 558.7674 | EGL |
| 822 | 920578.5499 | 219299.7869 | 558.5549 | EGL |
| 823 | 920601.5832 | 219320.2814 | 558.2433 | EGL |
| 824 | 920618.645 | 219345.8994 | 558.0012 | EGL |
| 825 | 920633.1475 | 219366.3938 | 557.7043 | EGL |
| 826 | 920651.9154 | 219391.1579 | 557.3645 | EGL |
| 827 | 920663.0055 | 219411.6523 | 557.2191 | EGL |
| 828 | 920672.3895 | 219434.7086 | 557.0962 | EGL |
| 829 | 920686.3537 | 219469.5043 | 556.8129 | EGL |
| 830 | 920703.7017 | 219492.9472 | 556.5029 | EGL |
| 831 | 920716.7126 | 219516.3901 | 556.347 | EGL |
| 832 | 920736.6627 | 219553.7251 | 556.0245 | EGL |
| 833 | 920759.2149 | 219582.3776 | 555.6988 | EGL |
| 834 | 920733.1931 | 219393.966 | 556.4466 | EGL |
| 835 | 920753.1432 | 219399.1756 | 556.3404 | EGL |
| 836 | 920776.5628 | 219406.1216 | 556.2141 | EGL |
| 837 | 920796.5129 | 219412.1994 | 556.0857 | EGL |
| 838 | 920585.7359 | 219237.68 | 558.2883 | EGL |
| 839 | 920605.686 | 219253.3086 | 558.0145 | EGL |
| 840 | 920624.7687 | 219271.5419 | 557.756 | EGL |
| 841 | 920642.1166 | 219286.3023 | 557.519 | EGL |
| 842 | 920659.4645 | 219299.3261 | 557.2803 | EGL |
| 843 | 920675.945 | 219314.9547 | 557.0569 | EGL |
| 844 | 920564.051 | 219190.7941 | 558.6371 | EGL |
| 845 | 920590.0729 | 219196.8719 | 558.2306 | EGL |
| 846 | 920614.36 | 219202.0815 | 557.8517 | EGL |
| 847 | 920636.0448 | 219207.291 | 557.5247 | EGL |
| 848 | 920650.7905 | 219209.0275 | 557.312 | EGL |
| 849 | 920669.0058 | 219213.3688 | 557.0516 | EGL |
| 850 | 920688.0885 | 219217.7101 | 556.7786 | EGL |
| 851 | 920712.3756 | 219222.0513 | 556.4298 | EGL |
| 852 | 920570.9902 | 219159.5369 | 558.574 | EGL |
| 853 | 920587.4707 | 219154.3274 | 558.329 | EGL |
| 854 | 920603.9512 | 219148.2496 | 558.0831 | EGL |
| 855 | 920622.1665 | 219142.1718 | 557.8013 | EGL |
| 856 | 920642.1166 | 219136.9623 | 557.4924 | EGL |

| 857 | 920654.2601 | 219132.621 | 557.3046 | EGL |
|-----|-------------|------------|----------|-----|
| 858 | 920671.608 | 219126.5432 | 557.0363 | EGL |
| 859 | 920686.3537 | 219122.2019 | 556.8081 | EGL |
| 860 | 919990.8444 | 219318.3032 | 569.1104 | EGL |
| 861 | 920820.5913 | 219418.1735 | 555.9241 | EGL |
| 862 | 920855.2387 | 219428.213 | 555.7989 | EGL |
| 863 | 920882.5919 | 219435.5144 | 555.7897 | EGL |
| 864 | 920914.504 | 219445.5539 | 555.7913 | EGL |
| 865 | 920949.1514 | 219453.768 | 555.7908 | EGL |

## 5.2  Appendix B: Laboratory Test Results

**Trail Pit No.1**

| Sieve Sizes (mm) | Each Sieve Passing % |
|------------------|----------------------|
| 14.0 | 98.7 |
| 10.,0 | 96.1 |
| 6.3 | 93.42 |
| 5.0 | 90.53 |
| 2.0 | 83.5 |

**Trail Pit No.2**

| Sieve Sizes (mm) | Each Sieve Passing % |
|------------------|----------------------|
| 14.0 | 100 |
| 10.0 | 99.4 |
| 6.3 | 97.0 |
| 5.0 | 94.7 |
| 2.0 | 90.3 |

**Trail Pit No.3**

| Sieve Sizes (mm) | Each Sieve Passing % |
|------------------|----------------------|
| 14.0 | 100 |
| 10.0 | 99.9 |
| 6.3 | 98.1 |
| 5.0 | 97.5 |
| 2.0 | 96.7 |

**Trail Pit No.4**

| Sieve Sizes (mm) | Each Sieve Passing % |
|---|---|
| 14.0 | 100 |
| 10.0 | 100 |
| 6.3 | 99.3 |
| 5.0 | 98.5 |
| 2.0 | 99.2 |

**Trail Pit No.5**

| Sieve Sizes (mm) | Each Sieve Passing % |
|---|---|
| 14.0 | 100 |
| 10.0 | 100 |
| 6.3 | 100 |
| 5.0 | 100 |
| 2.0 | 100 |

## 5.3 Appendix C: Field pictures

Latitude: 8.314015
Longitude: 48.457037
Altitude: 512.5±27 m
Accuracy: 199.4 m
Time: 06-02-2024 10:33
Note: Garoowe, Nugal, Somalia


Latitude: 8.309476
Longitude: 48.45354
Elevation: 575.25±47 m
Accuracy: 5.5 m
Time: 06-02-2024 08:49
Note: Garoowe, Nugal, Somalia


Latitude: 8.322752
Longitude: 48.467316
Elevation: 576.35±40 m
Accuracy: 212.4 m
Time: 06-01-2024 12:55
Note: Garoowe, Nugal, Somalia

Latitude: 8.31799
Longitude: 48.454318
Elevation: 615.83±19 m
Accuracy: 211.6 m
Time: 06-01-2024 08:05
Note: Garoowe, Nugal, Somalia