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29 November 2013

SPECIALIST STUDY: SOIL CLASSIFICATION AND LAND CAPABILITY: Environmental Study for the Greater Soutpansberg Project: GENERAAL
RFQ No: GSP-RFQ-004

Attached please find the final Soil and land capability report for the Generaal Project.

Yours sincerely

……………………………… ……………………………………………

Setenane Nkopane
For Gudani/Eco Soil Consortium

Francois Botha
for Gudani/Eco Soil Consortium

Final Soil Specialist Report on the Environmental Study for the Greater Soutpansberg Project: GENERAAL

RFQ No: GSP-RFQ-004

Compiled

By

Report by F. Botha and A. M. Hattingh

November 2013

STATEMENT OF INDEPENDANCE AND PROFESSIONAL AFFILIATION

We, the undersigned, hereby declare that we are not involved in any way with Coal of Africa Limited.

We conducted this survey in a scientific and impartial manner and declare that the findings of this report are free from influence or prejudice.

………………………………

Setenane Nkopane
For Gudani/Eco Soil Consortium

Field of expertise:

…………………………………………

Francois Botha
for Gudani/Eco Soil Consortium

Field of expertise: Soil classification and land capability studies

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Astrid Hattingh
For Gudani/Eco Soil Consortium
Field of expertise: Soil Scientist and GIS Specialist

Date: 2013/11/29

EXECUTIVE SUMMARY

Coal of Africa Limited (CoAL) requested a detailed EIA study for the proposed opencast mining operations at the Greater Soutpansberg: GENERAAL.

- Arenite, Basalt, Dolerite, Gneiss, Marble, Mudstone, Shale and Sedimentary rocks serves as parent material for the soils and has an influence on soil properties of the area. Parent materials are illustrated in Figure 3. According to the 1:250 000 land types map the seven specific ecotopes for the area under investigation are mainly red to yellow apedal soils, as well as shallow Glenrosa/Mispah soils and Rocky areas (Figure 4).

- The topography of the area varies between level plains to a rolling landscape with slopes of 2-3% (largest parts of the area), open high hills or ridges, as well as high hills and ridges (small areas in the south western parts of the area).

- The climate of the area is typified by warm to hot summers with low rainfall and high evaporation and dry warm winters. An assessment of the long-term rainfall records, indicate a mean annual rainfall of between 306 to 639mm within the study area.

- According to previous studies, combined with the present study the following land use areas were found: total 23234ha.
    - Commercial (or cleared) land: 324ha. (168ha irrigated and 156ha dry land)
    - Degraded: Forest and woodland: 149ha.
    - Thicket and Bushland: 22487ha.
    - Woodlands: 50.1ha
    - Wetlands: 224ha

- A number of farms (were not surveyed due to accessibility problems (Figure 1). The Land Capability of areas not surveyed in this study, were extrapolated from previous land type and land capability data obtained from Dept. Agriculture and Fisheries (2013) and presented in Figure 9. The accuracy of these extrapolations is, however questionable considering the scale at which the data was generated. The classes in

Figure 9 are not according to the four defined classes of the Chamber of Mines Guidelines (1991).

- Approximately 16519ha of the total project area was surveyed. The soil investigation on the proposed area was done with a soil auger on a grid system (1observation/9ha for the footprint and 1observation/25ha for the mining right area). The soils were classified according to the SA Taxonomic system. Soils were grouped into soil associations with the same physical characteristics e.g. colour, texture, and depth.
- Different soil properties of the surveyed areas are illustrated in Figures 11 to 13.
- Approximately (324ha) in the project area are presently under cultivation (156ha dry land and 168ha irrigated).
- Rainfall is in general too low for rain-fed crop production; however areas near the hills have higher rainfall (even 500 to 639mm as indicated in Figure 7). As a result of low rainfall, high temperatures (high evapotranspiration), susceptibility to compaction, present erosion and erodibility of the soils in the area, the soils are not always optimal for rain fed crop production.
- Approximately 3282ha of the study area is deeper than 75cm and can be regarded as good for crop production when rainfall permits or when high quality water for irrigation is available.
- Almost the entire area has very low clay contents of between 2 and 10% in the topsoil, which makes it susceptible for wind erosion.
- The majority of area have soils with low Profile available water capacities (PAWC (<100mm). This confirms that suitability for irrigation is limited to the very deep soils on the south western portion of the study area. This suitability is dependent on the availability of sufficient good quality irrigation water sources.
- Shallow soils and surface rock are present throughout the study area. Areas classified for grazing have presently low basal grass cover and are dominated by Mopane shrub field and will be discussed in detail by the biodiversity report. Present land use of these shallow soils is cattle and game farming, but carrying capacity is questionable due to poor physical soil quality (erosion susceptibility, shallow soils, surface rock and poor climatic conditions).
- Water for irrigation purposes is drawn directly from the Nzhelele Dam irrigation scheme. Seven samples were taken by WSM Leshika on the Mutamba River and two extra samples for the Makhado Mine monitoring report (P29-P30, Table 8 and

9, Surface water report). According to the surface water report Sample S Mon-13 reflects the water quality of the Nzhelele Dam. Though pH is high and there are elevated levels of Chloride, it falls within the acceptable criteria for irrigation water. The quality of this water sample does not pose any limitation to irrigation or crop production at present.

- Forty nine (49) samples of boreholes throughout the study area were analysed. Boreholes are not being used for irrigation purposes at present.

  A summary of the water quality problems for irrigation purposes of each water sample is given in Table 12. The quality of boreholes varies throughout the study area. The following water quality parameters are problematic in the water samples:
  - Sodium (Na) levels: 24 samples of the 49 have high levels of sodium, which can create various soil physical problems e.g. poor infiltration, dispersion and inhibition of plant growth.
  - Chloride (Cl) levels: 19 samples of the 49 have high levels of Chloride, which is detrimental to certain crops.
  - Other combined problems are high pH values, high electrical conductivity (EC) values, high total dissolvable solids (TDS), high Magnesium (Mg) and Manganese (Mn) values, creating imbalances in nutrient uptake and soil fertility.
  - Some of the water samples only have minor suitability constraints and can be used for irrigation if it is well managed. Water samples were taken during the winter and it is recommended to make a continual assessment of water quality during the year, since it can change significantly during the year.

- A combination of variables, which include topography, climate and water quality were then used to obtain land capability for the surveyed area according the Chamber of Mines Classification (Table 3). The results are illustrated in Figure 15.

- Table 15 presents the different categories and areas for the **surveyed area** according to the Mining classification:

  - Arable land 3282ha (14.1%)
  - Grazing areas 7728ha (33.3%)
  - Wilderness areas 5623ha (22.7%)
  - Wetland areas 244ha (1.1%).

- There are significant differences between the information presented in Figure 9 and Figure 15 respectively. The differences are due to the small scale of survey that was used with the land type study compared to the more detailed soil survey for this specific project. From the differences between Figures 9 and 15 and it can be concluded that it is crucial to do a more detailed soil investigation on the farms not yet surveyed, in order to obtain a better and more accurate assessment of the land capability and agricultural potential.

- The agricultural potential of the soils were classified according to Klingebiel and Montgomery (1961) (Table 4 and 5).

    - 3282ha is classified as arable soils according to the mining classification. Although there are areas of deep soils, these soils are marginal for dry-land crop production due to climatic and erosion restrictions. As a result of low rainfall, high temperatures (high evapotranspiration), susceptibility to soil compaction, wind erosion potential, the soils in the area study are not recommended for rain fed dry land crop production. These soils are suitable for irrigation and is classified as class III agricultural potential

- Soils of this area have a marginal dry land potential. Disturbance of soils will, however, have a long term to permanent impact on the land capability and agricultural soil potential. Special measures must be implemented in the soil stripping and rehabilitation process to restore the soils to an arable and grazing potential (see Appendix 1). Specialist consultation is needed for the wind erosion potential of the area during stock piling and the soil stripping process.

- If mining should be allowed in the area the following is recommended:
    - Specialist consultation is needed for the severe wind erosion potential and other possible impacts of the area during stock piling and the soil stripping process.
    - Limit impacts to footprint areas to keep physical impacts as small as possible.
    - Specific control measures are needed to control erosion and water run-off to prevent excessive surface run-off from the site.
    - Areas for road and site lay-out should be minimized.
    - Dust generation and vehicle associated pollution must be minimized.

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GLOSSARY OF TERMINOLOGY

- **A-Horizon (30)**. The depth of the topsoil horizon.
- **B-Horizon (100)**. The bottom end of the sub-soil horizon.
- **G** – The percentage (G3 = 30%) of gravel soil (>2mm) in the total soil profile. This portion has a huge influence on the water holding capacity and water movement (permeability) in the soil.
- **R** – The percentage of rocks in the profile. This has an influence on land preparation as well as the water holding capacity of the soil.
- **Restriction layer:** It can be rock fragments, soil structure or hydromorphic soil conditions that can limit root development.
- **Profile available water capacity (PAWC) –** It is a calculation between the AWC multiplied with the effective rooting depth (ERD). TAM values are therefore the most important value to determine from an irrigation design and scheduling perspective. It is also mentioned as total available moisture (TAM)
- **Effective rooting depth (ERD)**. This is the average depth that roots will develop under irrigation or where they are limited by an impeding layer. The effective rooting depth is the most important from a management perspective, which includes irrigation design, water holding capacity, drainage and nutrition.
- **Topsoil**: Is defined as the A-Horizon and a portion of the red and yellow apedal A-Horizon where microbial activity takes place and the majority of the plants hair roots occur.

- **Soil Forms:** Soil Forms are identified according to the SA Taxonomic Soil Classification system
- **Kriging or kriged:** A group of geostatistical techniques to interpolate the value of a random attribute (e.g., depth or clay content, of the landscape as a function of the geographic location) at an unobserved location from observations of its value at nearby locations.

1. INTRODUCTION

A broad soil classification, soil chemical analysis and agricultural potential were determined on approximately 16519ha to get baseline information regarding soil potential, land use and land capability. Due to accessibility problems a few of the farms not could be surveyed. In addition, profile pits could not be opened due to limitations with access and time constraints, as land owners are hosting hunters in the peak hunting season.

The farms surveyed, not surveyed or partly surveyed during this study are illustrated in Map 1.

The following farms were fully surveyed on the recommended grid:

- Kleinenberg
- Bekaf
- Juliana
- Coen Britz
- Boas
- Van Deventer
- Chase
- Stayt
- Nakab
- Schuitdrift
- Mount Stuart
- Terblanche

The following farms were partly surveyed:

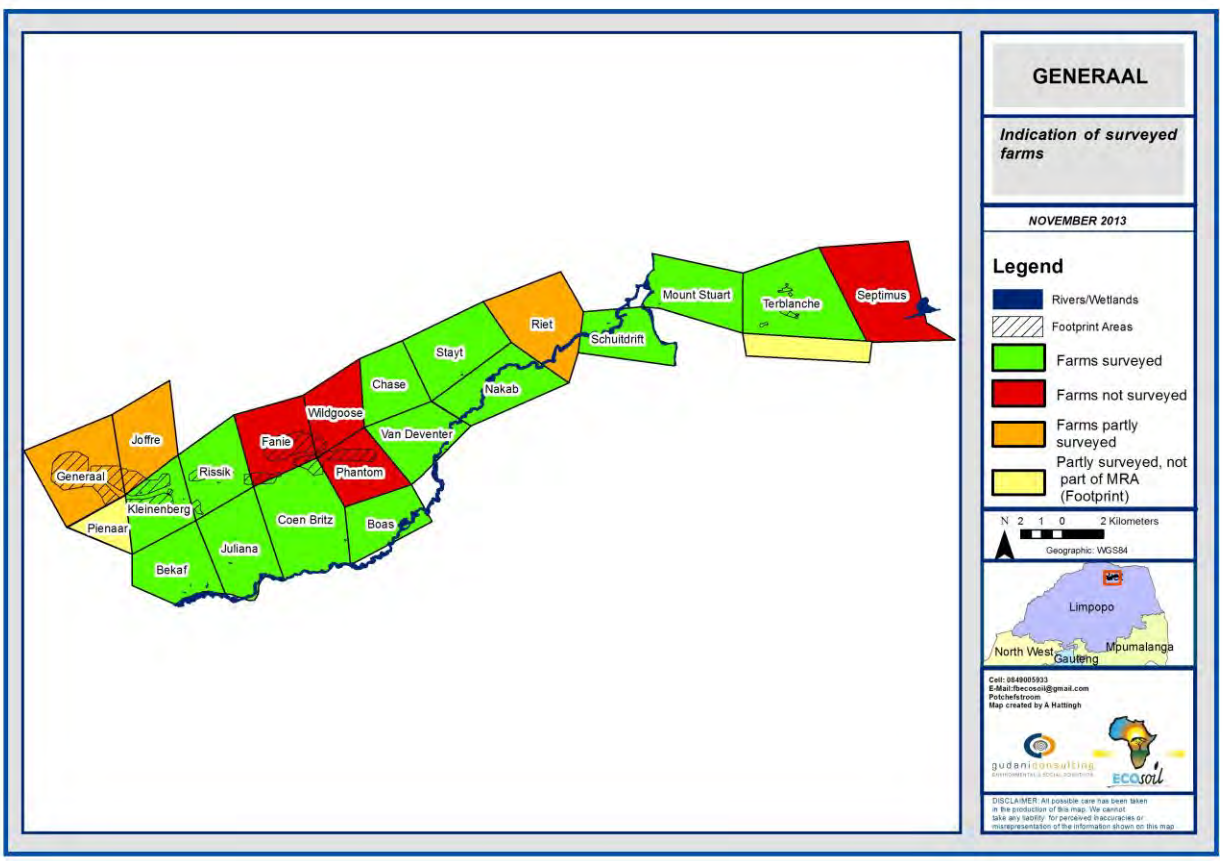
- Generaal
- Joffre
- Rissik
- Riet

No soil surveys were done on the following farms due to accessibility problems:

- Wildgoose
- Phantom
- Fanie
- Septimus

Although not part of the original MRA, small areas on Pienaar and Keerweder were also surveyed and illustrated, since parts of the footprints are situated on these farms.

Figure 1: Map showing farms surveyed, partly surveyed and not surveyed



The soil investigation on the proposed area was done with a soil auger on a grid system. Applying these criteria where possible to soils that were mapped based on the limitations of the soils' chemical and physical characteristics and site constraints. A combination of these variables was then used to obtain the land capability and agricultural potential of the soils.

Soils were classified in terms of the Taxonomic System for South Africa. Land capability of the study area was classified into four classes (wetland, arable land, grazing land and wilderness) according to Coaltech 2020/ Chamber of Mines of SA 2007 and Chamber of Mines Guidelines (1991).

2. TERMS OF REFERENCE (ToR)

The ToR for the soil assessment is outlined as follows:
To perform the necessary soil impact assessment required to support the applications. It should include (as a minimum):

- Detail soil, land use and land capability mapping
- Potential impact and quantification thereof (as far as possible) on soils, land use and land capability
- Recommendations for mitigation measures to reduce the identified impacts
- Conceptual rehabilitation plan based on soil types - no soil utilisation plan required at this stage due to limited information on infrastructure and mining footprints

The following sampling intensity to be used:

- Larger MRA area - Broad Reconnaissance (500m grid, 1 observation per 25 ha)
- Resource footprint - Intensified Reconnaissance (300m grid, 1 observation per 9 ha).

3. PROBLEM STATEMENT AND STUDY OBJECTIVE

Soils occurring on the proposed development area will be disturbed during the mining operation. Any medium to long-term impacts after mining needs to be limited. The purpose of this study is to identify the present soil quality in terms of soil forms, as well as their physical and chemical characteristics and how they will react to any disturbance.

4. PROJECT TEAM

Complete Curriculum Vitae's are summarised in Appendix 2.

Table 1: List of the team members

SPECIALISTS	FUNCTION	QUALIFICATION
S. Nkopane	Project Management, Liaison and communication	M.Sc., Environmental Management
F Botha	Soils project leader	B.Sc. (Hon), Pedology
A.M. Hattingh	Pedologist, GIS Specialist	M.Sc. (Soil Science)
J.M. Hattingh	Pedologist, Soil Chemist	M.Sc. (Engineering geology)
J.L. Pauer	Pedologist	B.Sc. (Hon,) Pedology
JHA Thiart	Pedologist	Soil Pedology Technician
MJ Botha	Pedologist	Soil Pedology Technician

5. IDENTIFICATION OF RELEVANT LEGAL REQUIREMENTS AND GUIDELINES

A soil classification and agricultural potential study is required with every EIA where agricultural land is concerned.

6. INVESTIGATIVE METHODOLOGY AND TECHNIQUES

The investigation commenced conducting the following actions:

- The collation and evaluation of available information.
- A soil survey was conducted on a total area of approximately 16612ha during this study.

- The soil survey involved the traversing of the area on a grid base using a conventional bucket hand auger (1.5 m in length) to investigate and log the soil depths. Approximately 741 observation points were surveyed in the study area (Figure 2). Selected terrain information, topography and any other infield data of significance, and of relevance to the investigation, was used.
- The land capability of the study area was classified according to soil depth and PAWC, as well as the elevation of the area. Observation point data was transformed with a process called kriging to a 100 by 100meter grid (1ha). On this grid basis it was decided in which of the four represented land potential groups (arable land, grazing, wilderness or wetland) each hectare falls, as is outlined by guidelines from the Chamber of Mines (1991). Wetlands were first delineated and polygons for the other groupings were then drawn from the kriged data. Detached areas smaller than one hectare was ignored.
- Profile Available Water Capacity (PAWC) was calculated by using soil form, soil depth and clay content.
- The data was recorded and stored in an electronic format (data base), and the information was then mapped with the ArcGIS program (See Figures 1 to Figure 15). Figures were created based on GPS information (Geographic: WGS 84). The field information was used to determine the Land capability.
- Twenty seven top and sub soil samples (Table 9) were taken for chemical analysis. Soil samples were sent to an accredited laboratory, namely NVirotek Laboratory at Brits (South Africa) for chemical analyses. pH (KCl), P (Bray 1), K, Ca, Mg Na and S (ammonium acetate) were determined. Ratios, CEC and percentages were calculated from the soil analyses.
- The positions of the samples are indicated in Figure 2. The chemical results were recorded in Table 9.
- Forty nine water samples were taken from boreholes across the study area by WSM Leshika. The dataset was used to interpret water quality for irrigation purposes. Results are summarized in Table 10 and problems encountered for irrigation purposes are indicated in Table 12.

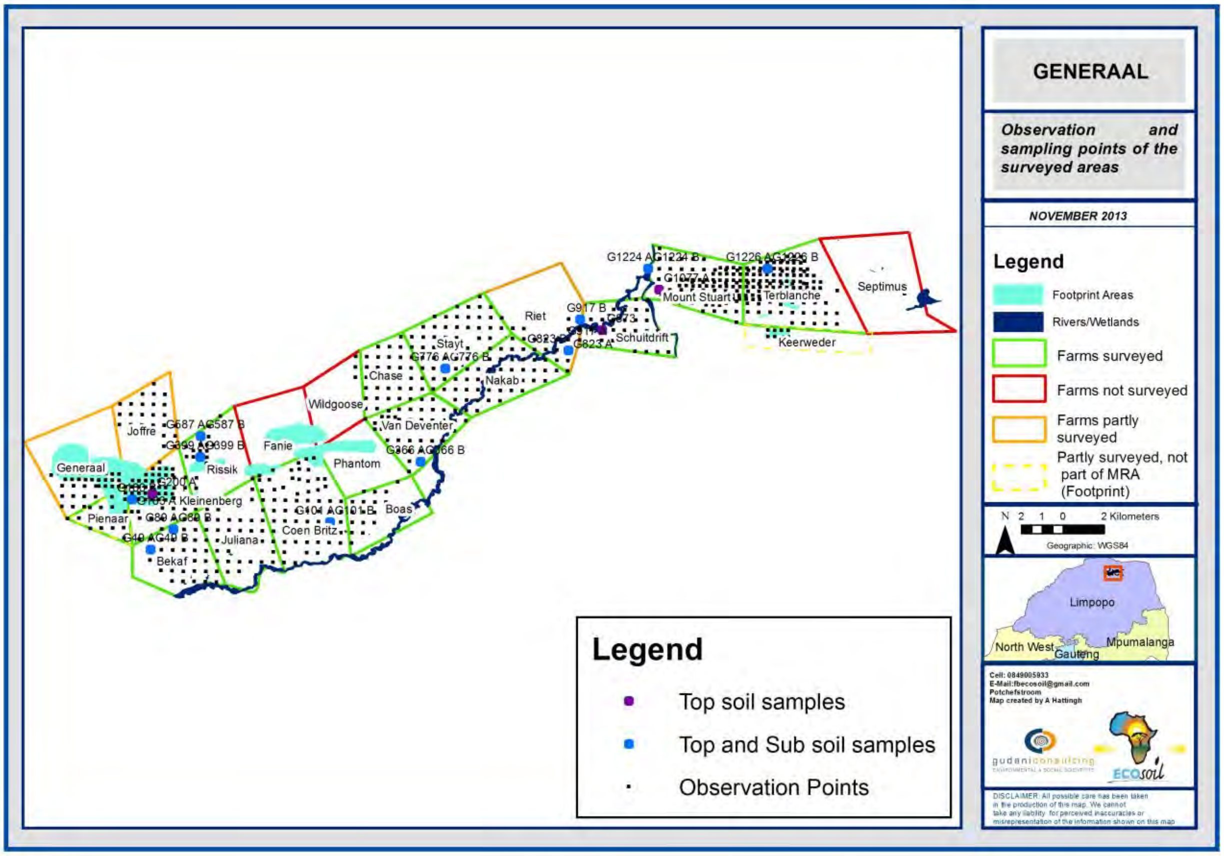
6.1 SOIL CLASSIFICATION

The investigation of the soils involved the traversing of the area on a grid base where possible, using a conventional bucket auger to investigate and log the soil characteristics. The following sampling intensity was used:

- Larger MRA area - Broad Reconnaissance (500m grid, 1 observation per 25 ha).
- Resource footprint - Intensified Reconnaissance (300m grid, 1 observation per 9 ha).

It was not possible to open profile pits due to restraints in terms of accessibility and time. Selected terrain information, topography and other infield data of significance, and of relevance to the soil investigation, was also recorded and stored in an electronic format (data base), and the information mapped on a recognised GIS system. Twenty seven top and sub soil samples were taken for chemical analysis (Positions where the samples were taken are indicated in Figure 2).

Figure 2: Observation and soil sampling points



Identification and classification of soil profiles was carried out using the TAXONOMIC SYSTEM FOR SOUTH AFRICA (*Soil Classification working group, 1991*). Land capability of the study area was classified into four classes (wetland, arable land, grazing land and wilderness) according to Coaltech 2020/Chamber of Mines of SA (2007) and Chamber of Mines Guidelines (1991). In this way, standardised soil identification and communication is allowed by use of the names and numbers given to the soils classified. The procedure adopted when classifying soil profiles is as follows:

a. Demarcate master horizons
b. Identify applicable diagnostic horizons by visually noting physical characteristics such as:
   - Depth
   - Texture
   - Structure

- Mottling
- Visible pores
- Concretions

c. Determine from a. and b. the appropriate Soil Form

6.2 INFORMATION SYSTEMS

The following sources of information were utilized:

- Initial maps supplied by Jacana
- Preliminary site layout plans
- ENPAT: Geology, Land use land capability, Land use, Land types
- Topo maps:
  - 2229DB Mopane,
  - 2230 Tshipese,
  - 2229DD Wyllie's Poort
- Climate: Rasters University of Natal
- Remote sensing information:
  - SRTM data
  - *Google Earth*™ image; digital image - Background and cultivated fields
- Esri shape file information, ArcGIS.
- The Dept. of Agriculture's website (Agis) was used to determine land types.
- The Taxonomic system for South Africa was used to identify soil forms on the proposed site.
- Land Capability Classification Coaltech 2020/ Chamber of Mines of SA (2007) and Chamber of Mines Guidelines (1991).

7. GENERAL BACKGROUND INVESTIGATION

7.1 PARENT MATERIALS

The lithology of the area is:
Fine-grained felsic, siliciclastic sedimentary, as well as mafic and ultramafic volcanic rocks. It consists of arenite, basalt, dolerite, gneiss, marble, mudstone, sedimentary sands and shale.

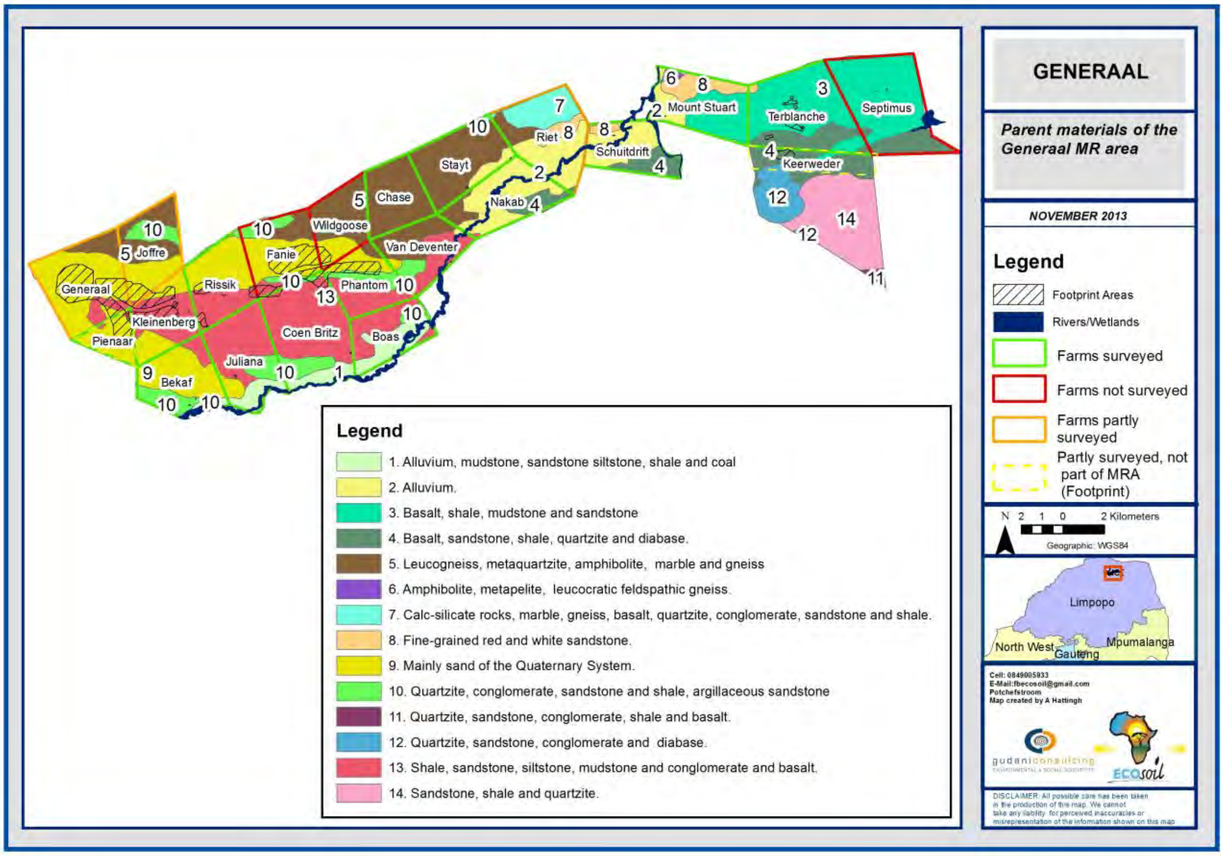
Footprints in the western parts are mainly on sand of the Quaternary System as well as on shale, sandstone, siltstone, mudstone and conglomerate and basalt. Footprints in the Mount Stuart area are situated on basalt, shale, mudstone and sandstone and the footprint on Keerweder is situated on basalt, sandstone, shale, quartzite and diabase.

The regional parent materials of the area are illustrated in Figure 3. The following parent materials are found and have an influence on the soil properties.

1. Alluvium, mudstone, sandstone, siltstone, shale and coal of the Clarens Formation and undifferentiated strata of the Karoo Sequence.
2. Alluvium.
3. Basalt of Letaba Formation; shale, mudstone and sandstone of the Klopperfontein and Solitude Formations, Karoo Sequence.
4. Basalt, sandstone, shale and quartzite of the Waterberg Group. Diabase also present.
5. Beit Bridge Complex, Malala Drift Formation; leucogneiss, metaquartzite, and amphibolite. Gumbu Gneiss, marble, gneiss; metaquartzite and amphibolite.
6. Beit Bridge Complex; amphibolite and metapelite of the Malala Drift Group with leucocratic feldspathic gneiss of the Gumbu Group.
7. Calc-silicate rocks, marble, scapolite rocks and leucocratic quartz-feldspathic gneiss of the Gumbu Group, Beit Bridge Complex; basalt, quartzite, conglomerate, sandstone and shale of the Soutpansberg Group, Stayt Formation.

8. Fine-grained red and white sandstone of the Clarens Formation, Karoo Sequence.
9. Mainly sand of the Quaternary System.
10. Quartzite, conglomerate, sandstone and shale of the Stayt Formation, Soutpansberg Group; argillaceous sandstone of the Clarens Formation, Karoo Sequence.
11. Quartzite, sandstone and conglomerate of the Wyllies Poort Formation with, in the south, sandstone, conglomerate, shale and basalt of the Fundudzi Formation, Soutpansberg Group. Diabase dykes and sills are common.
12. Quartzite, sandstone and conglomerate of the Wyllies Poort Formation, Soutpansberg Group. Also diabase.
13. Shale, sandstone, siltstone, mudstone and conglomerate of the Karoo Sequence; also Sibasa-Basalt.
14. Soutpansberg Group, Nzhelele Formation; sandstone, shaly in places as well as quartzite.

Figure 3: Parent materials of the Generaal study area



7.2 LAND TYPES

Eleven land types are found in the study area (Figure 4. Land types Fb360, IB311 and IB442 are illustrated on the Farm Keerweder but do not form part of the MRA. The numbers of the text corresponds with the number in Figure 4. Land types found in the study area, in the ranking order of area covered, are:

7.2.1 Ae269:RED-YELLOW APEDAL, FREELY DRAINED SOILS.

- Red apedal soils deeper than 300 mm deep and has a high base status. The soils have favourable physical properties. Soil depth may be restricted in some areas. Soils have excessive drainage, high erodibility and low natural fertility. Soils highly suited to arable agriculture where climate permits.
- 3927ha.

- Parent material is: shale, sandstone, siltstone, mudstone and conglomerate of the Karoo Sequence; also Sibasa-Basalt.
- Soil depth is generally between 450mm - 750mm.

7.2.2 Ae305: RED-YELLOW APEDAL, FREELY DRAINED SOILS.

- Red soils with high base status and deeper than 300 mm. Soils may have restricted soil depth in some areas. Soils have excessive drainage, high erodibility and low natural fertility. Freely drained, structureless soils, with favourable physical properties. Soils are generally of poor suitability for arable agriculture.
- 3645ha.
- Parent material is: Mainly sand of the Quaternary System.
- Soil depth is generally less than 750mm.
- Clay content is on average less than15%.
- Plant available water content is between 41 - 60 mm, indicating low potential soils.

7.2.3 Ah89: RED-YELLOW APEDAL, FREELY DRAINED SOILS.

- Red and yellow with a high base status and usually less than 15% clay. Soils are of intermediate suitability for arable agriculture where climate permits.
- 3632ha.
- The parent material is of the Beit Bridge Complex, Malala Drift Formation; leucogneiss, metaquartzite, and amphibolite. Gumbu Gneiss, marble, gneiss; metaquartzite and amphibolite.
- Soil depth is between 450mm - 750mm.
- Plant available water content is between 41 - 60 mm.

7.2.4 Ae265: RED-YELLOW APEDAL, FREELY DRAINED SOILS.

- Red apedal soils with a high base status deeper than 300 mm. It has no dominant soil potential class. Soils are freely drained, structureless soils and have favourable physical properties, but may have restricted soil depth, excessive drainage, high erodibility and a low natural fertility.

- 2871ha.
- Parent material is: Basalt of Letaba Formation; shale, mudstone and sandstone of the Klopperfontein and Solitude Formations, Karoo Sequence.
- Soil depth is generally between 450mm - 750mm
- Plant available water content is between 41 - 60 mm, indicating low potential soils.
- Clay content is on average less than15%.
- Clay content is on average less than 15%.
- Plant available water content is between 61 - 80 mm.

7.2.5 Ah88: RED-YELLOW APEDAL, FREELY DRAINED SOILS.

- Red and yellow soils with a high base status. The soils have favourable physical properties, but may have restricted soil depth, excessive drainage, and high erodibility risk and have a low natural fertility. Soils are highly suited to arable agriculture in areas where soil depth and climate permits.
- 1999ha.
- The parent material is alluvium.
- Soils have usually less than 15% clay.
- Soil depth ranges between 450mm - 750mm.
- Plant available water content is between 61 - 80 mm.

7.2.6 Ib312: MISCELLANEOUS LAND CLASSES.

- Non soil land classes (rocky area) with miscellaneous soils. This area has restricted land use options. Not suitable for agriculture or commercial forestry; suitable for conservation, recreation or water catchments. May have water-intake from other areas.
- 1241ha.

- Parent material is: Quartzite, conglomerate, sandstone and shale of the Stayt Formation, Soutpansberg Group; argillaceous sandstone of the Clarens Formation, Karoo Sequence.
- Soils are less than 450mm deep and the clay content is less than 15%.
- Plant available water content is between 21 - 40 mm, indicating very low potential soils.

7.2.7 Fb358: GLENROSA AND/OR MISPAH FORMS (but other soils may occur).

- Soils are classed as lithosols (shallow soils on hard or weathering rock) and have restricted soil depth; associated with rockiness, but may receive water runoff from associated rock. Soils are not suitable for arable agriculture, but are suitable for forestry or grazing where climate permits. Lime is rare or absent in upland soils but generally present in low-lying soils.
- 1075ha.
- Parent material is basalt, sandstone, shale and quartzite of the Waterberg Group. Diabase may also be present.
- Soil depth is less than 450mm and clay content less than 15%.
- Plant available water content is between 21 - 40mm, indicating very low potential soils.

7.2.8 Ia151: MISCELLANEOUS LAND CLASSES.

- Undifferentiated deep deposits. Soils are freely drained, structureless and have favourable physical properties, but may have restricted soil depth in some areas, have excessive drainage, high erodibility, low natural fertility. Soils are highly suited to arable agriculture where climate permits.
- 763ha.
- The parent material is alluvium, mudstone, sandstone, siltstone, shale and coal of the Clarens Formation and undifferentiated strata of the Karoo Sequence.
- Soil depth is generally deeper than 750mm and the clay content is between 15% - 35%.

- Water holding capacity is between 81 - 100 mm.

7.2.9 Ib313: MISCELLANEOUS LAND CLASSES.

- Rock areas with miscellaneous soils. The area is classified as a non-soil land class. It has restricted land use options. It is not suitable for agriculture or commercial forestry, but may be suitable for conservation, recreation or as water catchments. These areas may have water-intake from other areas.
- 430ha.
- Parent material is fine-grained red and white sandstone of the Clarens Formation, Karoo Sequence.
- Soils are less than 450mm deep and the clay content is less than 15%.
- Plant available water content is between 0-20 mm, indicating very low potential soils.

7.2.10 Fc481: GLENROSA AND/OR MISPAH FORMS (but other soils may occur).

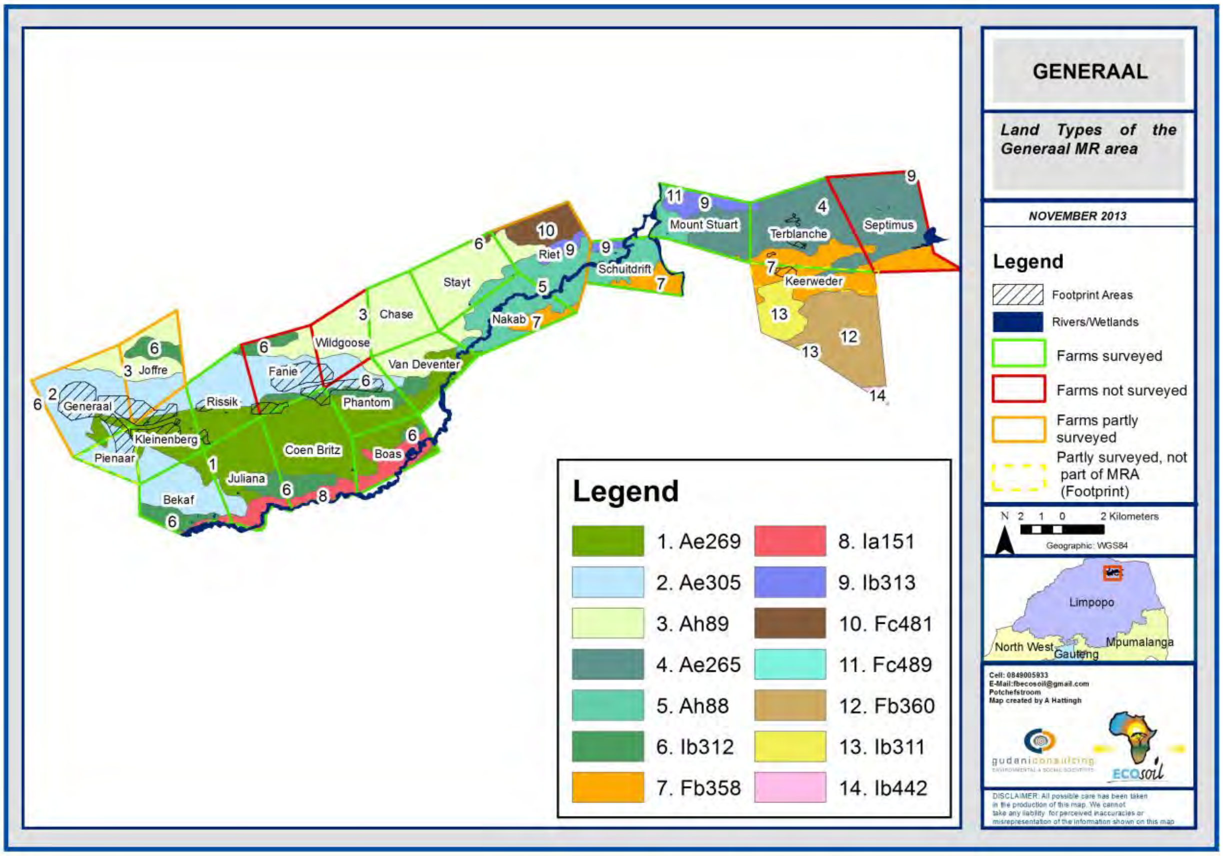
- Soils are classed as lithosols (shallow soils on hard or weathering rock) and have restricted soil depth; associated with rockiness, but may receive water runoff from associated rock. Lime is generally present in the entire landscape. Soils are not suitable for arable agriculture, but are suitable for forestry or grazing where climate permits.
- 406ha.
- The parent material is calc-silicate rocks, marble, scapolite rocks and leucocratic quartz-feldspathic gneiss of the Gumbu Group, Beit Bridge Complex; basalt, quartzite, conglomerate, sandstone and shale of the Soutpansberg Group, Stayt Formation.
- Soil depth is generally less than 450mm and the clay content less than 15%. Plant available water content is between 21 - 40mm, indicating very low potential soils.

7.2.11 Fc489: GLENROSA AND/OR MISPAH FORMS (other soils may occur).

- Soils are classed as lithosols (shallow soils on hard or weathering rock) and have restricted soil depth with associated with rockiness, but may receive water runoff from associated rock. Soils are not suitable for arable agriculture, but are suitable for forestry or grazing where climate permits. Lime generally present in the entire landscape.
- 39ha.
- The parent material is of the Beit Bridge Complex; amphibolite and metapelite of the Malala Drift Group with leucocratic feldspathic gneiss of the Gumbu Group. Soil depth is generally less than 450mm and the clay content less than 15%.
- Plant available water content is between 21 - 40mm, indicating very low potential soils.

Land types Fb 360, Ib311 and Ib442 are not described in the text, since they only occur on the Farm Keerweder, on the area not affected by the mining operations which does not form part of the MRA.

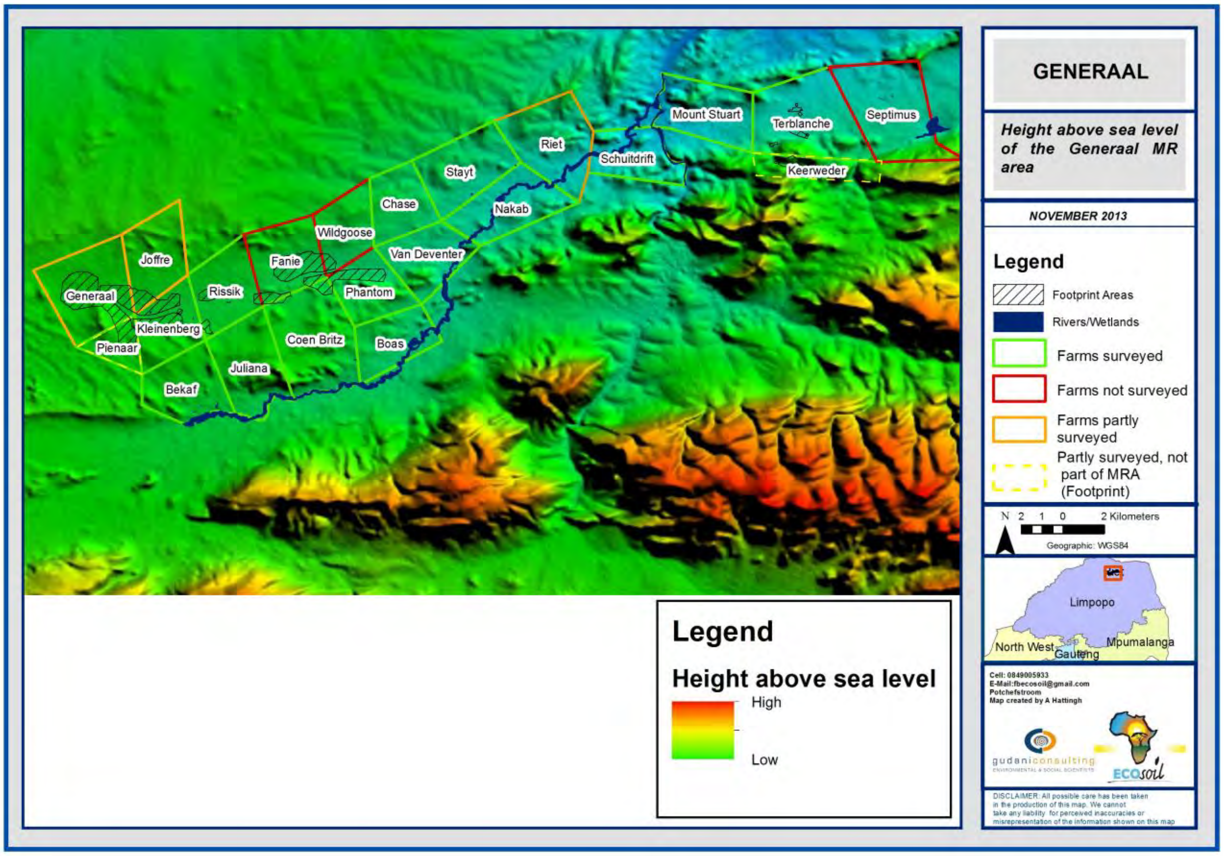
Figure 4: Land-types of the Generaal study area



7.3 TOPOGRAPHY

Topography of the area is illustrated in Figure 5. The southern parts of the project area is characterised by hills and ridges and forms part of the Soutpansberg.

Figure 5: Topography of the Generaal study area

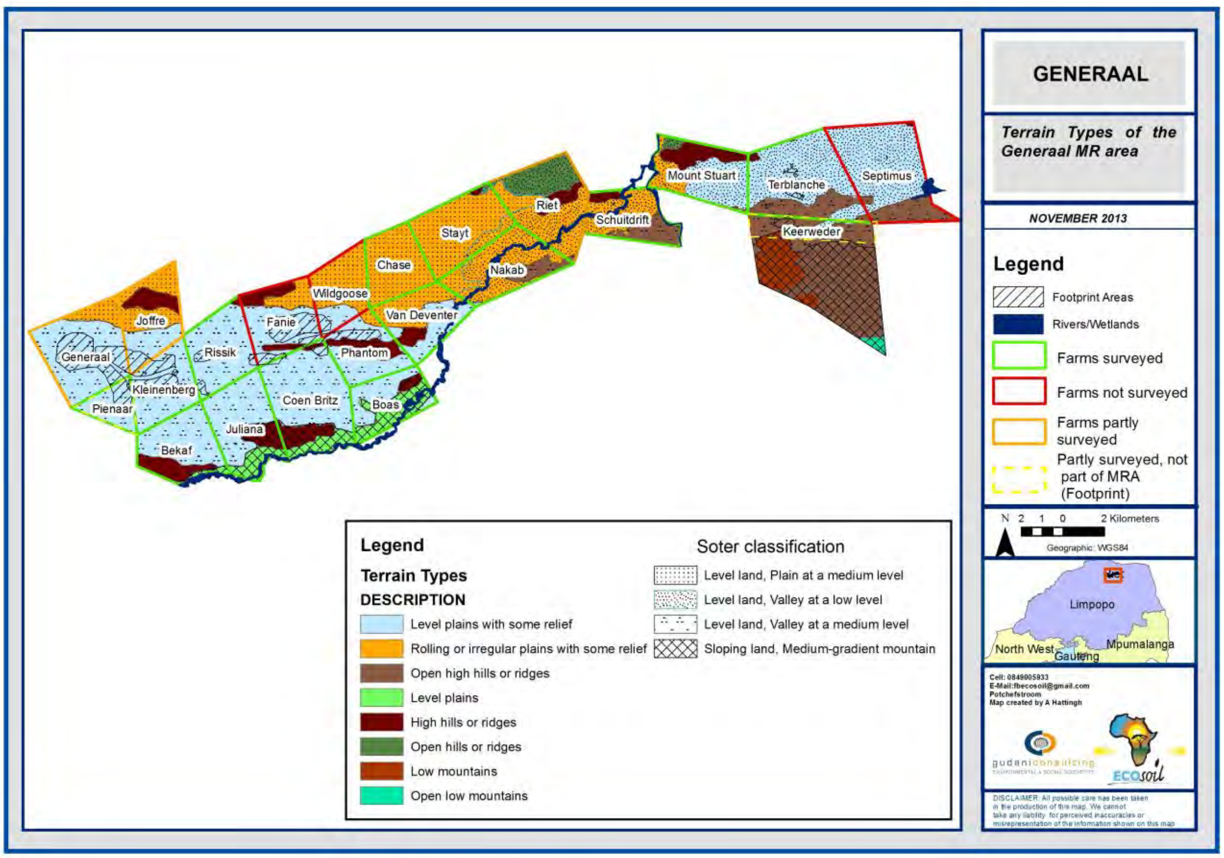


The Generaal study area (Figure 6) exists mainly of six terrain types, namely:

- Level plains with some relief. The majority of the area falls in this class. Almost the entire Mount Stuart parts, as well as the far western parts, are situated in this terrain type.
- Rolling or irregular plains with some relief is mainly present in the central parts of the area, especially on the farms Wildgoose, Chase, Stayt and Schuitdrift as well as some parts of Joffre and Generaal.
- High hills or ridges are present on isolated areas on the farms Juliana and Coen, Britz, Phantom and Van Deventer, Fanie, Joffre, Bekaf, Schuitdrift and Riet.

- Level plains on the areas of the flood planes of the Mutamba River in the southern parts of the area.
- Open high hills or ridges are present in the south eastern parts of the study area.
- Open hills or ridges are present on the farm Riet and a small area on Mount Stuart.

Figure 6: Terrain types of the Generaal study area



7.4 CLIMATE

The climate of the area is typified by warm to hot summers with low rainfall and high evaporation and dry warm winters. The area is generally frost free.

Precipitation is strongly seasonal with about 85% of the yearly rainfall falling in the summer months (October to March). Monthly variations in climate throughout the area are given in Table 2. The hills and ridges are predominantly orientated in an east-west direction. It has a very strong influence on the climatic pattern of the area. An assessment of the long-term rainfall records indicates a mean annual rainfall that varies between 306 to 639mm. Highest rainfall is present on the southern parts of the farms Terblanche and Septimus (and on the farm Keerweder). The rainfall is lowest on the Mount Stuart farm in areas next to the Nzhelele River. Rainfall is generally higher in the eastern parts next to the hills and is decreasing gradually to the northern and western parts further from the hills.

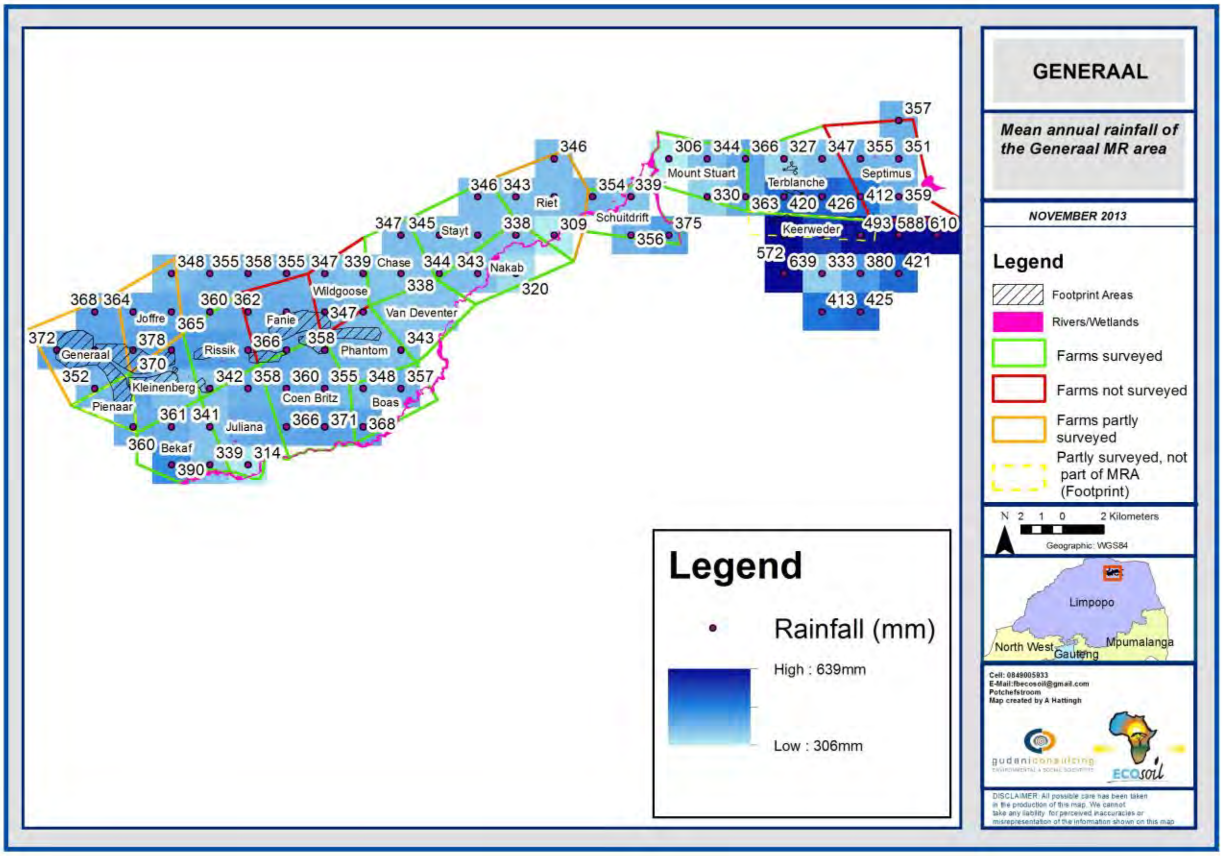
Highest temperatures are found during December and January in the area of Septimus and Terblanche in the most northern parts of the study area. Summer temperatures are generally lower in the higher lying mountainous areas in the east. Coldest temperatures are found during July on the farm Generaal, as well as on the flood planes of the southern Matumba River. Rainfall, as well as mean maximum and mean minimum temperatures of the Generaal study area are summarised in Table 2. From the ranges found in Table 2 it can be concluded that climate, especially rainfall during the summer, varies considerably throughout the area and also over relatively short distances. These variations have a very large influence on the agricultural potential of the area. The enormous diversity in possible crop and variety selections, as well as climatic needs per crop, makes it difficult to characterize typical adaptive capacities and strategies for the area. All year round irrigated crop production is possible as the winters are frost free. However the suitability for arable crop production depends highly on quality of irrigation water, terrain- and soil properties. Areas with very low rainfall or either areas with high hills and difficult terrain is not suitable for dry land agriculture. Rainfall distribution patterns are presented in Figure 7.

Table 2: Mean monthly rainfall, maximum and minimum temperatures

Month	Mean Rainfall mm	Mean Maximum Temperatures C°	Mean Minimum Temperatures C°
January	52-114	27.7-31.8	17.8-20.1
February	43-96	27.1-31.0	17.7-19.9
March	19-62	26.3-30.2	17.1-18.6
April	9-26	25.2-28.5	14.8-15.9
May	0-6	23.5-26.6	10.4-13.0
June	0-2	20.9-23.9	6.9-10.3
July	0	21.1-23.9	6.7-10.0
August	0-1	22.7-25.9	9.0-11.3
September	0-2	24.4-28.1	12.5-13.4
October	14-31	26.9-29.6	14.7-16.4
November	30-65	27.2-30.8	16.3-18.4
December	45-95	27.3-31.2	17.4-19.6
Total aver	306-639		

The Area falls mainly in two Quaternary Water Catchment areas. The western and central parts of the area are situated in Catchment A80F and the eastern parts (farms Terblanche, Septimus and northern parts of Mount Stuart) are situated Catchment in A80G.

Figure 7: Mean annual rainfall of the Generaal study area



7.5 PRESENT LAND USE

Only 324ha of the total project area is cleared for crop production and 168ha is irrigated.

- Crop production is taking place on the farms Schuitdrift, Generaal, Rissik and Mount Stuart as is indicated in yellow in Figure 8. Schuitdrift and Mount Stuart have 168ha of fields under irrigation.
- The majority of area is presently covered with thicket bushveld of the Mopani veld (Acocks classification) woody species and used for grazing purposes for either cattle or game farming.
- Very small areas are covered with high density woody species, especially on the farms Schuitdrift and Mount Stuart along the riversides.

- Small areas has no or very scarce basal cover especially on the farms Boas, Nakab and Generaal. Due to the very low clay contents of the area degraded areas are highly susceptible to wind erosion. Water erosion may also occur.

According to previous studies, combined with the present study the following land use areas were found: total 23234ha.

Commercial (or cleared) land: 324ha. (168ha irrigated and 156ha dry land)

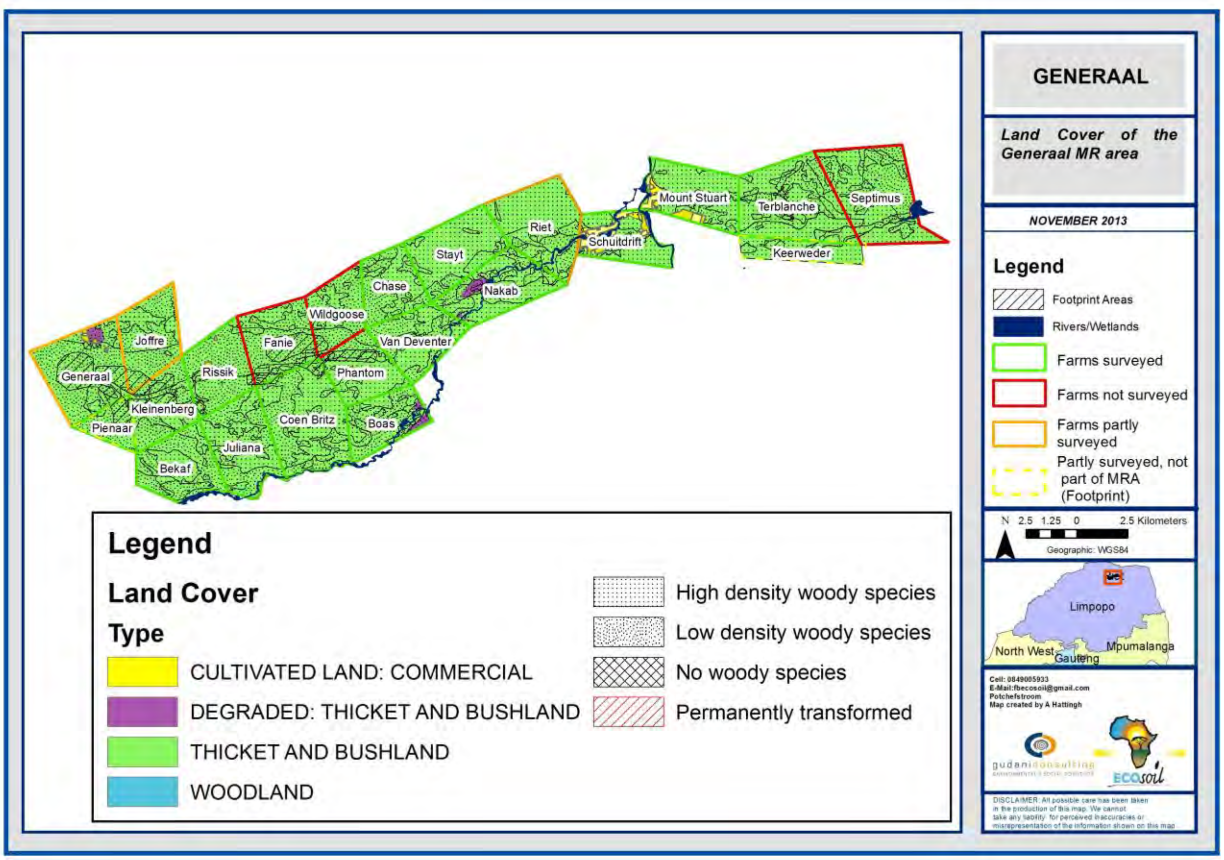
Degraded: Forest and woodland: 149ha.

Thicket and Bushland: 22487ha.

Woodlands: 50.1ha

Wetlands: 224ha

Figure 8: Present land cover of the study area



7.6 LAND CAPABILITY OF FARMS NOT SURVEYED DURING THIS STUDY

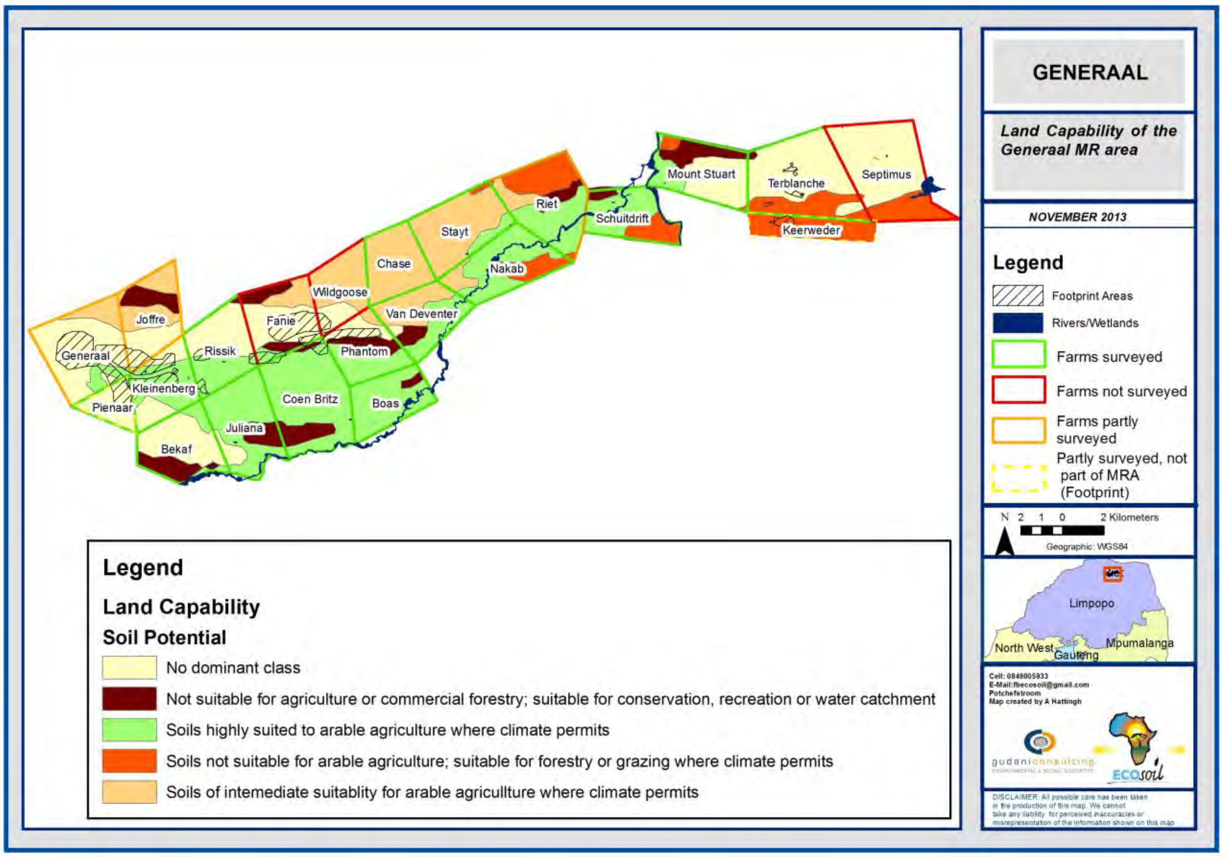
The farms Fanie, Wildgoose, Phantom and Septimus were not surveyed during this study due to reasons as outlined in Point 1. Joffre, Generaal and Riet were only partly surveyed. Since large areas of the footprint are situated on these farms existing historic land capability information was gathered to bridge the knowledge gap in the areas not surveyed. This information was derived the Dept. of Agriculture and Fisheries data (2013) and from the ENPAT data base.

Land capability for areas not surveyed during this study can be derived from Figure 9. The accuracy of these extrapolations is questionable considering the scale at which the data was generated and should only be used in areas not surveyed. It will be necessary to do a proper soil survey of this area in order to determine the actual real land use potential of the entire area. According to the desk study the land capability can be classified in five land capability classes, they are as follow:

- Highly suited to arable agriculture where climate permits.
- Soils not suitable for arable agriculture, but suitable for forestry or grazing are found in the eastern parts. It is generally due to low rainfall.
- Soils of poor suitability for arable agriculture.
- Areas not suitable for agriculture or commercial forestry, but suitable for conservation, recreation or water catchment are found in the southern parts in the higher lying areas of the study area.
- Soils of intermediate suitability for arable agriculture.

From the data of the desk study the farms Fanie, portions of Generaal, Pienaar and Rissik and Wildgoose and Phantom are classified as "no dominant class". Huge variations in soil properties and potential are usually found in this class and because of the lack of the soil survey, no clear indication of land capability can be given in this case.

Figure 9: Land capability of the Generaal study area (information from previous studies)



7.7 LAND CAPABILITY AND AGRICULTURAL RATING

Land capability of the study area was classified into four classes (wetland, arable land, grazing land and wilderness) according to the Chamber of Mines Guidelines (1991). The criteria used for classification is summarized in Table 3.

Table 3: Criteria for Pre-Development Land Capability according to the Chamber of Mines Guidelines (1991)

Criteria for Wetland

- Land with organic soils or supporting hygrophilous vegetation where soil and vegetation processes are water determined.

Criteria for Arable land

- Land, which does not qualify as a wetland.
- The soil is readily permeable to a depth of 750 mm.
- The soil has a pH value of between 4.0 and 8.4.
- The soil has a low salinity and SAR
- The soil has less than 10% (by volume) rocks or pedocrete fragments larger than 100 mm in the upper 750 mm.
- Has a slope (in %) and erodibility factor (K) such that their product is <2.0
- Occurs under a climate of crop yields that are at least equal to the current national average for these crops.

Criteria for Grazing land

- Land, which does not qualify as wetland or arable land.
- Has soil, or soil-like material, permeable to roots of native plants, that is more than 250 mm thick and contains less than 50 % by volume of rocks or pedocrete fragments larger than 100 mm.
- Supports, or is capable of supporting, a stand of native or introduced grass species, or other forage plants utilisable by domesticated livestock or game animals on a commercial basis.

Criteria for Wilderness land

- Land, which does not qualify as wetland, arable land or grazing land.

7.8 LAND USE AND AGRICULTURAL POTENTIAL FORMS

The original concepts (Klingebiel & Montgomery, 1961) are as follow:

Table 4: Land use classes suited for cultivation according to Klingebiel & Montgomery (1961)

Land suited for cultivation	
Class I	Land in Class I has few limitations that restrict its use.
	It may be used safely and profitably for cultivated crops.
	The soils are nearly level and deep.
	They hold water well and are generally well drained.
	They are easily worked, and are either fairly well supplied with plant nutrients or are highly responsive to inputs of fertilizer.
	When used for crops, the soils need ordinary management practices to maintain productivity.
	The climate is favourable for growing many of the common field crops.
Class II	Land in Class II have some limitations that reduce the choice of plants or require moderate conservation practices.
	It may be used for cultivated crops, but with less latitude in the choice of crops or management practices than Class I.
	The limitations are few and the practices are easy to apply.
	Limitations may include singly or in combination the effects of:
	*Gentle slopes.
	*Moderate susceptibility to wind and water erosion.
	*Less than ideal soil depth.
	*Somewhat unfavourable soil structure and workability.
	*Slight to moderate salinity or sodicity easily corrected but likely to recur.
	*Occasional damaging flooding.
	*Wetness correctable by drainage but existing permanently as a moderate limitation.
	*Slight climatic limitations on soil use and management.
	Limitations may cause special soil-conserving cropping systems, soil conservation practices, water-control devices or tillage methods to be required when used for cultivated crops.
	Note: “Slight to moderate salinity or sodicity, easily corrected, but likely to recur” is taken to imply that strong subsoil acidity, costly to correct and likely to recur, would disqualify land from Class II.
Class III	High susceptibility to water or wind erosion or severe adverse effects of past erosion.
	It may be used for cultivated crops, but has more restrictions than Class II. When used for cultivated crops, the conservation practices are usually more difficult to apply and to maintain.
	Limitations restrict, singly or in combination, the amount of clean cultivation, time of planting, tillage, harvesting, choice of crops.
	Limitations may result from the effects of one or more of the following:
	The number of practical alternatives for average farmers is less than that for soils in Class II.
	*Moderately steep slopes.
	*Frequent flooding accompanied by some crop damage.
	*Very slow permeability of the subsoil.
	*Wetness or some continuing waterlogging after drainage.
	*Shallow soil depth to bedrock, hardpan, fragipan or claypan that limit the rooting zone and the water storage.
	*Low water-holding capacity.
	*Low fertility not easily corrected.
	*Moderate salinity or sodicity.
	*Moderate climatic limitations.
	Note: “Severe limitations” and “Low fertility not easily corrected” are taken to imply that land dominated by soils with severe subsoil acidity belongs in Class III.
Class IV	Land in Class IV has very severe limitations that restrict the choice of plants, require very careful management, or both.
	It may be used for cultivated crops, but more careful management is required than for Class III and conservation practices are more difficult to apply and maintain.
	Restrictions to land use are greater than those in Class III and the choice of plants is more limited.
	It may be well suited to only two or three of the common crops or the harvest produced may be low in relation to inputs over long period of time.
	In sub-humid and semi-arid areas, land in Class IV may produce good yields of adapted cultivated crops during years of above average rainfall and failures during years of below average rainfall.
	Use for cultivated crops is limited as a result of the effects of one or more permanent features such as:
	*Steep slopes.
	*Severe susceptibility to water or wind erosion or severe effects of past erosion.
	*Shallow soils.
	*Low water-holding capacity.
	*Frequent flooding accompanied by severe crop damage
	*Excessive wetness with continuing hazard of waterlogging after drainage.
	*Severe salinity or sodicity.
	*Moderately adverse climate.

Table 5: Land use classes not-suited for cultivation according to Klingebiel & Montgomery (1961)

Land with limited use - generally not suited to cultivation	
Class V	Land in Class V has little or no erosion hazard but have other limitations impractical to remove that limit its use largely to pasture, range, woodland or wildlife food and cover. These limitations restrict the kind of plants that can be grown and prevent normal tillage of cultivated crops. Pastures can be improved and benefits from proper management can be expected.
	It is nearly level. Some occurrences are wet or frequently flooded. Other are stony, have climatic limitations, or have some combination of these limitations.
	*Bottomlands subject to frequent flooding that prevents the normal production of cultivated crops.
	*Nearly level land with a growing season that prevents the normal production of cultivated crops.
	*Level or nearly level stony or rocky land.
	*Ponded areas where drainage for cultivated crops is not feasible but is suitable for grasses or trees.
Class VI	Land in Class VI has severe limitations that make it generally unsuited to cultivation and limit its use largely to pasture and range, woodland or wildlife.
	Land in Class VI has continuing limitations that cannot be corrected, such as:
	*Steep slope.
	*Severe erosion hazard.
	*Effects of past erosion.
	*Stoniness.
	*Shallow rooting zone.
	*Excessive wetness or flooding.
	*Low water-holding capacity.
	*Salinity or sodicity.
	*Severe climate.
	Physical conditions are such that it is practical to apply range or pasture improvements, if needed, such as seeding, liming and fertilizing.
	Some occurrences can be safely used for the common crops, provided unusually intensive management is used. Some occurrences are adapted to special crops.
	Depending on soil features and climate, land in Class VI may be well to poorly suited to woodlands.
Class VII	Land in Class VII has very severe limitations that makes it unsuited to cultivation and that restrict its use largely to grazing, woodland or wildlife.
	Restrictions are more severe than those for Class VI because of one or more continuing limitations that cannot be corrected, such as:
	*Very steep slopes.
	*Erosion.
	*Shallow soil.
	*Stones.
	*Wet soil.
	*Salts or sodicity.
	*Unfavourable climate.
	Physical conditions are such that it is impractical to apply such pasture or range improvements as seeding, liming and fertilizing.
	Depending on soil characteristics and climate, land in Class VII may be well or poorly suited to woodland.
	In unusual instances some occurrences may be used for special crops under unusual management practices.
Class VIII	Land in Class VIII have limitations that preclude its use for commercial plant production and restrict its use to recreation, wildlife, water supply or aesthetic purposes
	Limitations that cannot be corrected may result from the effects of one or more of:
	*Erosion or erosion hazard.
	*Severe climate.
	*Wet soil.
	*Stones.
	*Low water-holding capacity.
	*Salinity or sodicity.
	Land in Class VIII cannot be expected to return significant on-site benefits from management for crops, grasses or trees, although benefits from wildlife use, watershed protection or recreation may be possible.
	Badlands, rock outcrop, sandy beaches, river wash, mine tailings and other nearly barren lands are included in Class VIII.

Table 6: Land capability classes to establish land use

LAND CAPABILITY CLASS	LAND USE OPTIONS	LAND CAPABILITY GROUPS
Class I	W F LG MG IG LC MC IC VIC	Arable land
Class II	W F LG MG IG LC MC IC	Arable land
Class III	W F LG MG IG LC MC	Arable land
Class IV	W F LG MG IG LC	Arable land
Class V	W F LG MG	Grazing
Class VI	W F LG MG	Grazing
Class VII	W F LG MG	Grazing
Class VIII	W	Wildlife
W - Wildlife LC - Poorly adapted cultivation		
F - Forestry MC - Moderately well adapted cultivation		
LG - Light grazing IC - Intensive, well adapted cultivation		
MG - Moderate grazing VIC - Very intensive, well adapted cultivation		
IG - Intensive grazing		
IG - Intensive grazing		

8. FAO IRRIGATION WATER QUALITY GUIDELINES

Table 7: Water quality guidelines used in this study

Potential irrigation problems	Units	Degree of restriction on use		
		None	Slight to moderate	Severe
Salinity (affects crop water availibility)				
EC_w	dS m^{-1}	<0.7	0.7-3.0	>3.0
or TDS	mg l^{-1}	<450	450-2000	>2000
Infiltration (affects infiltration rate of water into the soil; evaluate using Ecw and SAR together)				
SAR 0-3 and ECw=		>0.7	0.7-0.2	<0.2
SAR 3-6 and ECw=		>1.2	1.2 -0.3	<0.3
SAR 6-12 and ECw=		>1.9	1.9-0.5	<0.5
SAR 12-20 and ECw=		>2.9	2.9-1.3	<1.3
SAR 20-40 and ECw=		>5.0	5.0-2.9	<2.9
Spesific ion toxicity (effects sensitive crops)				
Sodium (Na)				
Surface irrigation	SAR	<3	3-9	>9
Sprinkler irrigation	meq l^{-1}	<3	>3	
Chloride (Cl)				
Surface irrigation	meq l^{-1}	<4	4-10	>10
Sprinkler irrigation	meq l^{-1}	<3	>3	
Boron (B)	mg l^{-1}	<0.7	0.7-3.0	>3.0
Miscellaneous effects (on susceptible crops)				
Nitrate NO_3-N	mg l^{-1}	<5	5-30	>30
Bicarbonate HCO_3^- (overhead sprinkling only)	meq l^{-1}	<1.5	1.5-8.5	>8.5
pH		Normal range 6.5 -8.4		

9. OBSERVATIONS

9.1 SOIL FORMS

The soils vary significantly in physical and chemical composition over the different areas. They are strongly influenced by the underlying rocks (geology) from which they were derived, as well as by their position in the landscape and the origin of the parent material (*in-situ* versus colluvium/alluvium derived).

The major soil forms that generally have similar characteristics were grouped together in soil associations to simplify the data for interpretation purposes (Figure 10). The soil physical properties of the different soil groups are presented in Table 8. Associations occurring on the proposed development and the number of soil form occurrences (in brackets), are as follow:

9.1.1 RED APEDAL SOILS

- **Hutton (Hu) [190]:** Has an Orthic A-Horizon over a Red Apedal A-Horizon over unspecified materials, like hard or weathered rock, stone or gravel.
- **Plooysburg (Py) [10]:** Has an Orthic A-Horizon over a Red Apedal A-Horizon over a hardpan horizon.

The depth of the apedal red soils in this study area ranges between 30cm to deeper than 150cm (average 100cm). Clay content of the top soil ranges between 3 and 28% (average 9.6%), at 50cm the clay content ranges between 3 and 32% (average 12.7%), at 100cm the clay content ranges between 3 and 45% (mean 12%), at 150cm the clay content ranges between 3 and 25% (average 9%).

9.1.2 YELLOW-BROWN APEDAL SOILS

- **Clovelly (Cv) [19]**: Has an Orthic A-Horizon over a Yellow Brown Apedal A-Horizon over unspecified materials, like hard or weathered rock, or gravel.
- **Askham (Ak) [5]:** Has an Orthic A-Horizon over a Yellow Brown Apedal A-Horizon over hardpan carbonate.

The average depth of the apedal yellow soils in this study area range from 45-150cm with an average of 86cm. Clay content of the top soil ranges between 3 and 15% (average 9.9%), at 50cm the clay content ranges between 5 and 32% (average 13.3%), at 100cm the clay content ranges between 5 and 18% (average 9.9%), at 150cm the clay content ranges between 5 and 18% (average 9%).

9.1.3 NEOCUTANIC SOILS

- **Oakleaf (Oa) [49]:** Has an Orthic A-Horizon over a Neocutanic B-Horizon over unspecified materials, without signs of wetness in the subsoil.

- **Gamoep (Gm) [4]:** Have an Orthic A-Horizon over a Neocutanic B-Horizon over a hardpan- or soft carbonate horizon respectively.
- **Tukulu (Tu) [2]:** Has an Orthic A-Horizon over a Neocutanic B-Horizon over unspecified materials, with signs of wetness in the subsoil.

In this study area the average depth of the neo-cutanic soils range from 40-150cm (average 90cm). Clay content in the top soil ranges between 12 and 25% (mean 17%), at 50cm the clay content ranges between 18 and 35% (average 25%), at 100cm the clay content ranges between 18 and 35% (mean 25%), at 150cm the clay content averages 35%.

9.1.4 CARBONATE SOILS

- **Coega (Cg) [80] and Brandvlei (Br) [3]**: Have an Orthic A-Horizon over a hardpan- or soft carbonate horizon respectively.

The depth ranges from 10-40cm (average 18cm). The clay content in the top soil ranges between 5 and 28% (average 15%)

9.1.5 NEOCARBONATE SOILS

- **Augrabies (Ag) [43]:** Has an Orthic A-Horizon over a Neocarbonate B on unspecified materials.
- **Prieska (Pr) [6] and Addo (Ad) [1]:** Have an Orthic A-Horizon over a Neocutanic B on a hardpan- or soft carbonate horizon respectively.

In this study area the average depth of the neocarbonate soils range from 40-150cm with an average of 89cm. Clay content in the top soil range between 13 and 28% (average 21.7%), at 50cm the clay content ranges between 15 and 38% (average 29.9%), at 100cm the clay content ranges between 22 and 45% (average 29%), at 150cm the clay content ranges between 22 and 38% (average 29%).

9.1.6 STRUCTURED SOILS

- **Shortlands (Sd) [2]:** Has an Orthic A-Horizon over a Red Structured B-Horizon. Although this soil form does not have Pedocutanic properties it has soil structure in the sub soil and only occurs once in the entire area. It is therefore grouped in this class
- **Swartland (Sw) [4]:** Has an Orthic A-Horizon over a Pedocutanic B- horizon on Weathered rock (saprolite).
- **Valsrivier (Va) [2]:** Has an Orthic A-Horizon over a Pedocutanic B-Horizon without signs of wetness in the sub-soil.

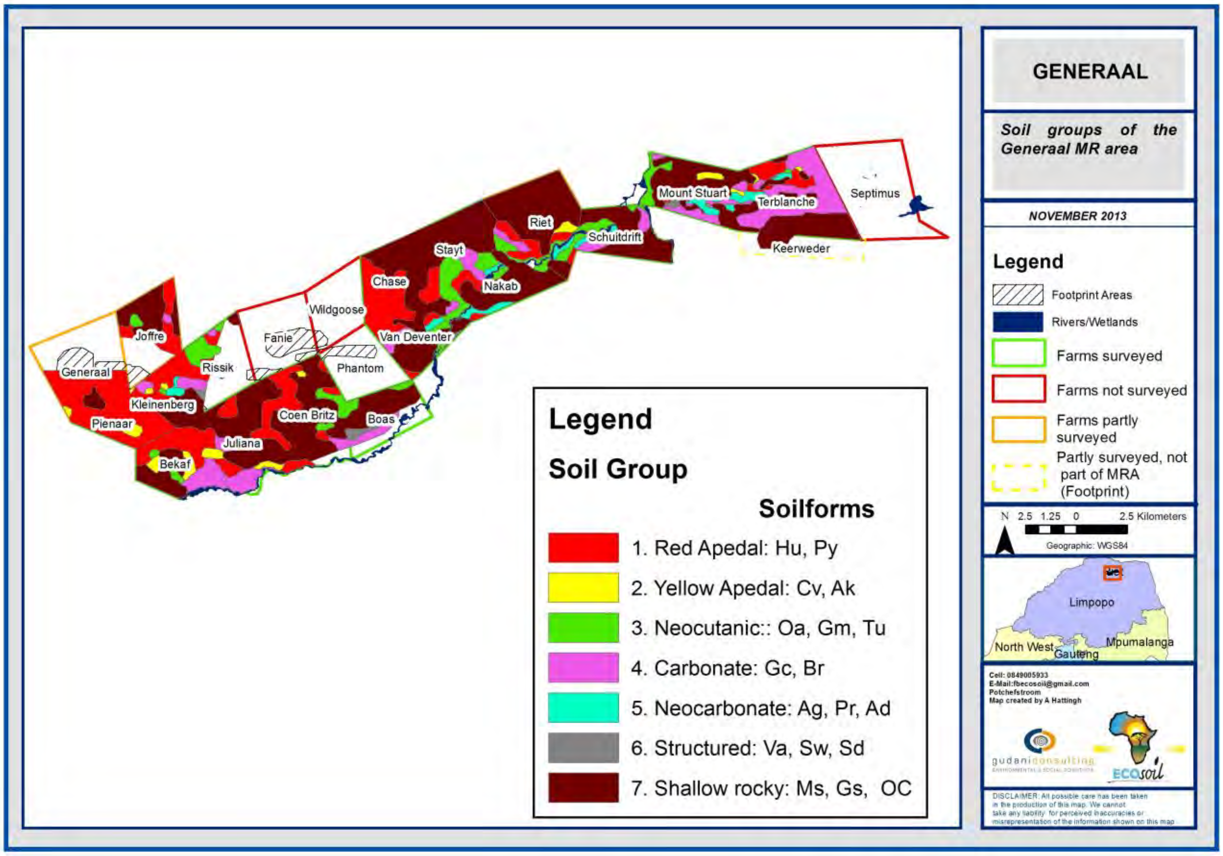
In this study area the average depth of the structured soils range from 30-100cm with an average of 61cm. Clay content in the top soil ranges between 15 and 40% (average 29%), at 50cm the clay content varies between 30 and 45% (average 39%).

9.1.7 SHALLOW ROCKY SOILS

- **Mispah (Ms) [201]:** Has an Orthic A-Horizon over hard rock.
- **Glenrosa (Gs) [120]:** Has an Orthic A-Horizon on a Lithocutanic B-Horizon.
- **Outcrop (OC) [2]:** No soil present, only bare rock.

The average depth of these soils varies from 0 to 45cm (average 21.2cm). The clay content in the top soil varies between 3 and 30% (average 15%).

Figure 10: Soil groups (associations) and forms of the study area



Although soil forms can give a slight indication of soil capability, it cannot give an indication of agricultural potential. Soil forms give an indication of expected soil colour, properties and soil forming processes.

- Large areas of the farms Generaal, Pienaar, Kleinenberg, Joffre, Chase and Bekaf are covered with Hutton and Clovelly soil forms. These deep soils can be considered as medium potential, where climatic conditions are favourable. However this is not the case in the project area and the potential of these soils are downgraded to Class III (due to climatic constraints), as is summarised in Table 16.
- Shallow rocky soils are dominant in the farms Coen Britz, Boas, Juliana, Stayt, Van Deventer, Nakab and Riet.

- Neocutanic soils are mainly found in small areas on the farms Schuitdrift, Riet and Rissik.
- Carbonate soils are found in some areas on the farms Bekaf, Juliana, Mount Stuart and Terblanche.

9.2 SOIL PHYSICAL PROPERTIES

Table 8 is a summary of the soil physical properties of the different soil groups.

Table 8: Summary of different soil physical properties of the soil groups

Properties	Soil Group 1	Soil Group 2	Soil Group 3	Soil Group 4	Soil Group 5	Soil Group 6	Soil Group 7
Soil association	Red Apedal	Yellow - brown Apedal	Neo-cutanic	Carbonate	Neo-carbonate	Structured Soils	Shallow, rocky
Soil forms	Hu, Py	Cv, Ak	Oa, Gm, Tu	Cg, Br	Ag, Pr, Ad	Sd, Sw, Va,	Ms, Gs
Dominant soil	Hutton	Clovelly	Oakleaf	Coega	Augrabies	Swartland	Glenrosa
Soil family	1200	1200	1120	1000	1120	1122	1100
Soil Depth cm	30-150	45-150	40-150	10-40	40-150	30-100	0-45
Average rooting depth cm	100	86	90	18	89	61	21
Infiltration rate	Fast 15-20mm/h	Fast 15-20mm/h	Slow 5-10mm/h	Very Slow <5mm/h	Slow 5-10mm/h	Very Slow <5mm/h	Slow 5-10mm/h
Consistency	Loose	Loose	Friable	Soft	Soft	Hard	Loose
Structure	Apedal	Apedal	Weak blocky	Apedal	Weak blocky	Strong blocky	Apedal
Clay % A (aver)	3-28(9.6)	3-15(9.9)	12-25(17)	5-28(15)	13-28(21.7)	15-40(29)	3-30(15)
Clay % 50cm	3-32(12.7)	5-32(13.3)	18-35(25)	Soil not 50cm	15-38(29.9)	30-45(39)	Soil not 50cm
Clay% 100cm	3-45(12)	5-18(9.9)	18-35(25)	-	22-45(29)	-	
Clay% 150cm	3-25(9)	5-18(9.9)	35	-	22-38(29)	-	
PAW mm/profile	24-179 (91)	41-161 (75)	24-201 (109)	4-153 (21)	53-205 (110)	43-138 (84)	0-65 (23)
Field capacity mm	40-344 (153)	65-279 (125)	38-392 (201)	7-286 (37)	95-412 (83)	92-282 (170)	0-122 (39)

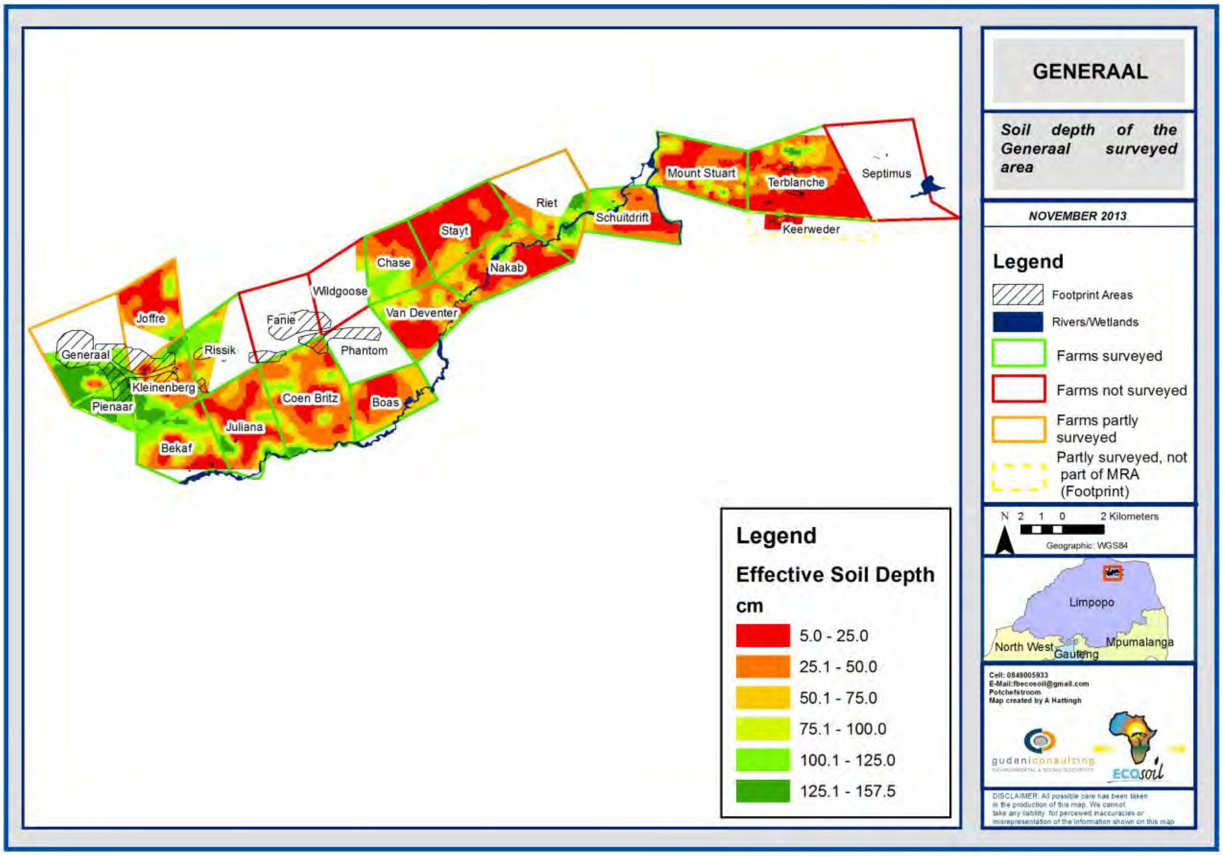
Wilting point mm	15-180 (62)	24-118 (50)	14-190 (93)	3-133 (16)	42-212 (102)	48-144 (86)	0-57 (17)
Drainage	Fast	Fast	Moderate	Poor	Moderate	Poor	Moderate
Gravel/Rocks A-Horizon	-	-	-	R1	G3	-	R5
Gravel/rocks B1 Horizon	G1	G1	G3	R6	G3	-	R
Gravel/rocks B2 Horizon	G1	G1	G3	-	G3	G3	-
Wetness	0	0	0	0	0	W1	0
Compactability	High	High	High	Moderate	High	Moderate	Low
Erodibility	Very High	Very High	High	Very High	Very High	High	Very High
Potential Nematode Infestation	High	High	Moderate	Low	Low	Low	High

Figures 11-13 shows the effective rooting depth, clay content of the A- Horizon and Profile Available Water capacity (PAWC) respectively.

- Deep soils (>100cm) are found predominantly in the western parts of the study area, mainly in the southern parts of the farms Generaal and Kleinenberg, as well as on the farms Rissik and the northern parts of Bekaf. Deep soils are also found on the south-western parts of Chase and north western parts of Van Deventer and the areas surrounding the river on the farms Riet and Schuitdrift. According to the Chamber of Mines (1991) classification (Table 3) these deep soils can be regarded as arable, especially under irrigation. According to the agricultural classification (Klingebiel & Montgomery, 1961) these soils are classified as classes III to IV as is outlined in Table 4 and 5 and the restriction being the low rainfall and sandy conditions.
- Very shallow soils with depths less than 50cm are found in the north-eastern parts of the area, especially on the farms Terblanche, Mount Stuart, and the section on Keerweder. These shallow soils are also found on Stayt and Nakab, east Schuitdrift, as well as the north-eastern parts of Chase.

Significant areas on the farms Joffre, Juliana, Boas and Van Deventer also have very shallow soils.

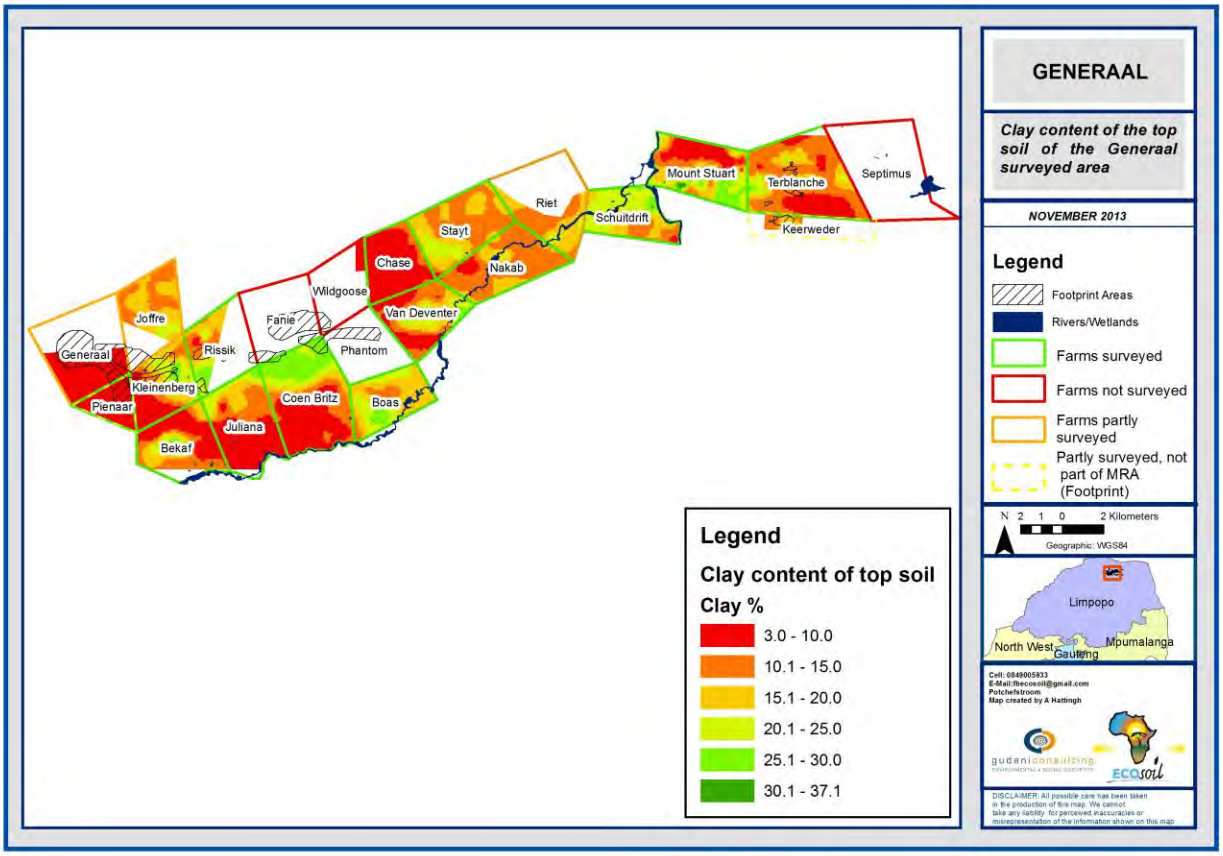
Figure 11: Effective rooting depth of the study area



Clay contents of the top soils are illustrated in Figure 13. Clay content of the top soil gives an indication of the susceptibility to soil erosion. The clay content of the top soils of almost the entire area is below 10%. These soils are prone to wind erosion. These soils should always be covered with vegetation to combat wind erosion.

It will be necessary to protect these low clay content areas from wind erosion and associated dust formation, if it is to be considered for moving soils during the mining process. Special attention is needed for this operation to combat wind erosion and specialists should be consulted.

Figure 12: Clay content (%) of the top soils

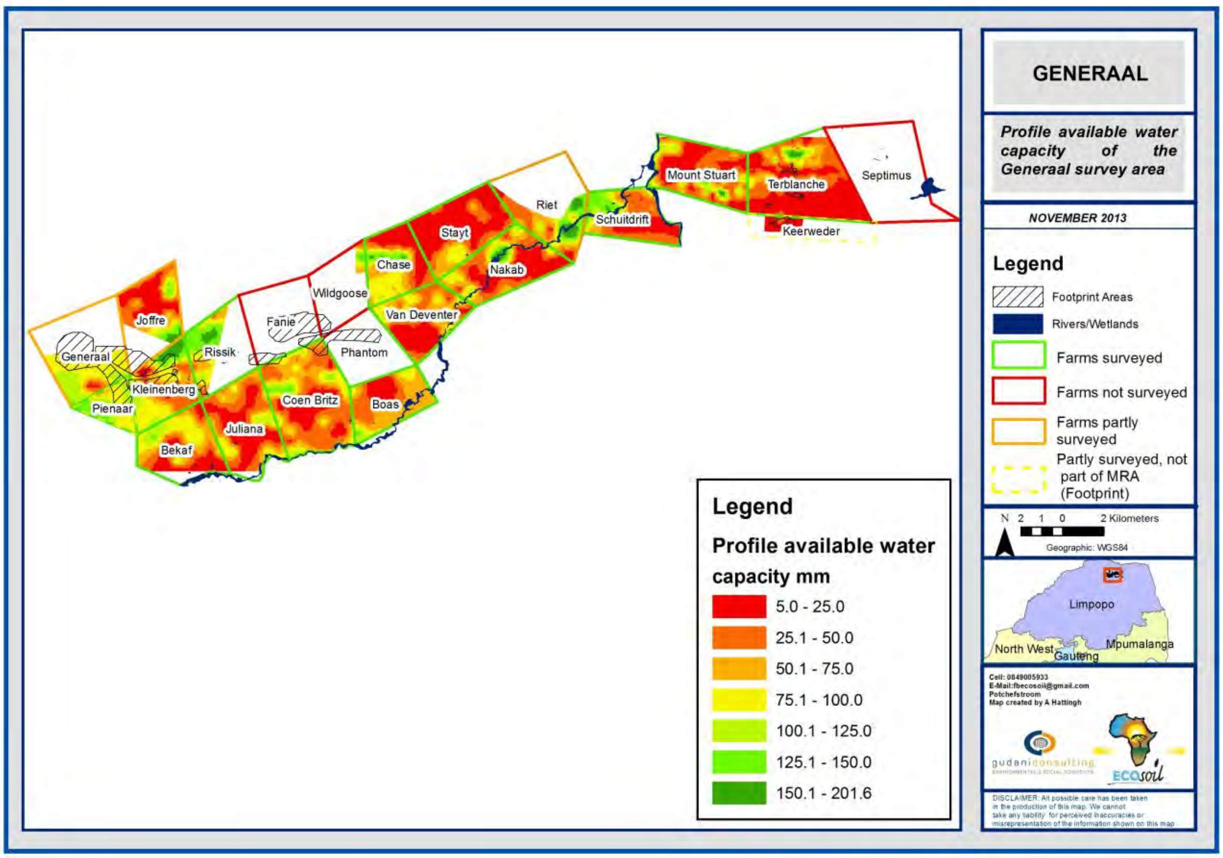


Profile available water capacity (PAWC) is illustrated in Figure 13. PAWC is the capacity of soil to keep a certain amount of water in the profile that can be used by a plant. The values are calculated from soil depth, soil texture (clay content) and soil forms. These combined factors give an indication of the potential of the soil for dry land crop production, as well as the amount of water that will be needed to fill the profile in the case of irrigation.

Large areas throughout the study area have low PAWC and ranges between 6 and 75mm (illustrated in brown, red and orange in Figure 13), which can be considered as sub-optimal for crop production purposes. Large areas with a low PAWC are mainly found on the farms Joffre, Bekaf, Juliana, Stayt, Nakab, Mount Stuart and Van Deventer.

Only relatively small areas on the farms Kleinenberg, Rissik, Pienaar, Generaal and Coen Britz can be considered as having medium water holding water capacities of 100-150mm (light to dark green hue in Figure 13). However, the rainfall of the area is too low to regard these areas of high value for dry land crop production, unless irrigated with **good** quality water and that there will be sufficient water available.

Figure 13: Profile available water capacity of the study area



9.3 SOIL CHEMICAL PROPERTIES

Table 9 is a copy of the soil analysis and co-ordinates of sample sites.

- The pH of most soil samples are close to neutral. This is an indication of the influence of the free lime in the soil profile.
- The phosphate (P) levels are generally extremely low. This can easily be rectified with fertilisers for cop production purposes.

- The Potassium (K) content of the soil samples varies between very low (lowest is 25mg kg^{-1}, which is too low for normal crop production), to more than 300mg kg-1, which can be regarded as high.
- Sample G1077 needs special attention. The cation content (K, Ca, Mg, and Na) of this sample is very high, but has high clay content. It is located on the farm Mount Stuart on a shallow soil with poor water holding capacity (PAWC). Although the values may seem extreme it has no major concerns and is in balance.
- Calcium (Ca) and Magnesium (Mg) levels are low to medium.
- Cation ratios are within acceptable ranges.
- The cation exchange capacities are generally low. This is an indication of the low clay% of the soil and the resulting low nutrient fertility.
- There is no indication of any potential salinity or sodicity in any of the soil samples.

Table 9: Soil analysis Report

SOILANALYSIS REPORT

NviroTek Labs

TEL:	088 303 2967	FAX:	086 683 7781
COMPANY:	Eco Soil	NAME:	Generaal
		DATE:	2013/10/24
ADRESS:	12 Olienhout Str	FARM:	
ADRESS:	Mierderpark Potchefstroom	EMAIL:	fbecosoil@gmail.com
CODE:	2551	FAX:	
TEL NO:	018 297 4826	ORDER NO:	

Ref No	Co-ordinates		pH (KCl)	PBray1	K	Na	Ca	Mg	EA.KCl	%Ca	%Mg	%K	%Na
	Longs	Lats		mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	cmol(c)/kg	%	%	%	%
G49 A	29.87622087	-22.7876	5.49	14	120	8	592	236	0.00	56.53	36.93	5.84	0.69
G49 B			6.12	1	86	11	1128	390	0.00	61.92	35.11	2.43	0.54
G89 A	29.886154	-22.7788	6.42	1	39	7	257	45	0.00	72.11	20.66	5.53	1.69
G89 B			5.07	1	35	8	166	40	0.00	64.78	25.75	6.92	2.55
G101 A	29.95434993	-22.7756	6.14	1	185	12	685	124	0.00	68.95	20.51	9.51	1.04
G101 B			6.52	1	341	11	883	168	0.00	65.81	20.49	13.01	0.69
G183 A	29.8682724	-22.7657	4.94	1	25	6	131	25	0.00	69.23	21.37	6.70	2.70
G183 B			4.41	1	25	6	72	24	0.12	47.35	25.52	8.37	3.34
G200 A	29.8770879	-22.7632	5.15	1	199	10	796	195	0.00	64.89	26.09	8.29	0.72
G366 A	29.99385576	-22.7493	6.11	4	166	9	321	81	0.00	58.80	24.27	15.56	1.38
G366 B			5.78	1	184	14	540	186	0.00	56.76	32.07	9.91	1.27
G399 A	29.89788061	-22.7474	5.10	4	143	9	371	122	0.00	56.94	30.64	11.20	1.22
G399 B			5.25	2	209	12	355	187	0.00	45.59	39.37	13.74	1.30
G587 A	29.89690162	-22.7339	5.20	1	125	9	387	111	0.00	60.32	28.47	9.97	1.25
G587 B			5.07	2	138	12	343	118	0.00	55.53	31.31	11.45	1.72
G776 A	30.00446729	-22.7089	6.16	2	265	9	803	399	0.00	50.14	40.88	8.48	0.50
G776 B			6.86	2	304	8	841	309	0.00	55.65	33.58	10.29	0.47
G823 A	30.0581422	-22.7008	6.09	7	189	9	1092	247	0.00	68.19	25.25	6.05	0.51
G823 B			6.75	1	81	17	1913	353	0.00	75.06	22.74	1.63	0.57
G873	30.07291961	-22.6921	5.67	3	37	6	141	91	0.00	44.71	47.48	6.02	1.79
G917 A	30.06329271	-22.6874	5.97	10	197	8	876	145	0.00	71.74	19.45	8.25	0.56
G917 B			6.26	1	98	13	1952	251	0.00	80.46	16.99	2.07	0.48
G1077 A	30.09760801	-22.6745	7.36	36	946	49	3380	670	0.00	67.53	21.95	9.67	0.86
G1224 A	30.09293724	-22.6654	6.36	20	333	17	814	267	0.00	56.66	30.45	11.85	1.05
G1224 B			6.96	6	134	35	1180	358	0.00	63.24	31.44	3.68	1.64
G1226 A	30.14479279	-22.6653	5.76	4	76	9	1003	374	0.00	60.35	36.86	2.34	0.45
G1226 B			5.68	1	55	16	1398	567	0.00	59.01	39.21	1.18	0.60

(Continues)

Ref No	Co-ordinates		Acid Sat	Ca:Mg	(Ca+Mg)/K	Mg:K	S-Value	Na:K	T	Density	S AmAc	EC	ESP	Clay	Silt	Sand
	Longs	Lats	%	1.5-4.5	10.0-20.0	3.0-4.0	cmol(+)/kg		cmol(c)/kg	g/cm3	mg/kg	µS/cm		%	%	%
G49 A	29.87622	-22.7876	0.00	1.53	16.00	6.32	5.23	0.12	5.23	1.60	0.91			13	1	86
G49 B			0.00	1.76	40.00	14.47	9.11	0.22	9.11	1.46	1.08	173.2	0.54	15	2	83
G89 A	29.88615	-22.7788	0.00	3.49	16.77	3.74	1.79	0.31	1.79	1.66	0.47			15	3	82
G89 B			0.00	2.52	13.08	3.72	1.28	0.37	1.28	1.67	0.60	22.1	2.55	19	3	78
G101 A	29.95435	-22.7756	0.00	3.36	9.41	2.16	4.97	0.11	4.97	1.57	2.48			17	1	82
G101 B			0.00	3.21	6.63	1.57	6.70	0.05	6.70	1.43	2.42	177.6	0.68	21	1	78
G183 A	29.86827	-22.7657	0.00	3.24	13.53	3.19	0.95	0.40	0.95	1.6588	0.7198			9	1	90
G183 B			15.42	1.86	8.71	3.05	0.64	0.40	0.76	1.6923	2.7726			10	7	83
G200 A	29.87709	-22.7632	0.00	2.49	10.97	3.15	6.14	0.09	6.14	1.4964	1.0305			16	8	76
G366 A	29.99386	-22.7493	0.00	2.42	5.34	1.56	2.73	0.09	2.73	1.69	1.38			13	1	86
G366 B			0.00	1.77	8.97	3.24	4.75	0.13	4.75	1.43	1.45	68.8	1.27	23	2	75
G399 A	29.89788	-22.7474	0.00	1.86	7.82	2.73	3.26	0.11	3.26	1.63	1.60			15	3	82
G399 B			0.00	1.16	6.18	2.86	3.89	0.09	3.89	1.46	1.95	49.3	1.3	19	3	78
G587 A	29.8969	-22.7339	0.00	2.12	8.91	2.86	3.20	0.12	3.20	1.56	2.56			15	2	83
G587 B			0.00	1.77	7.58	2.73	3.09	0.15	3.09	1.47	2.25	40.9	1.72	17	2	81
G776 A	30.00447	-22.7089	0.00	1.23	10.74	4.82	8.01	0.06	8.01	1.40	1.13			19	7	74
G776 B			0.00	1.66	8.67	3.26	7.56	0.05	7.56	1.52	1.40	70	0.47	17	5	78
G823 A	30.05814	-22.7008	0.00	2.70	15.45	4.17	8.00	0.08	8.00	1.55	0.70			16	8	76
G823 B			0.00	3.30	59.96	13.94	12.74	0.35	12.74	1.41	0.26	154.1	0.57	24	13	63
G873	30.07292	-22.6921	0.00	0.94	15.32	7.89	1.57	0.30	1.57	1.71	0.60			9	1	90
G917 A	30.06329	-22.6874	0.00	3.69	11.05	2.36	6.10	0.07	6.10	1.43	0.79	147.6	0.56	10	7	83
G917 B			0.00	4.73	47.13	8.22	12.13	0.23	12.13	1.34	1.15			16	11	73
G1077 A	30.09761	-22.6745	0.00	3.08	9.25	2.27	25.03	0.09	25.03	1.31	13.89			47	29	24
G1224 A	30.09294	-22.6654	0.00	1.86	7.35	2.57	7.18	0.09	7.18	1.58	1.78			19	5	76
G1224 B			0.00	2.01	25.76	8.55	9.33	0.45	9.33	1.44	2.04			23	6	71
G1226 A	30.14479	-22.6653	0.00	1.64	41.49	15.73	8.31	0.19	8.31	1.58	0.25			12	7	81
G1226 B			0.00	1.50	83.39	33.29	11.84	0.51	11.84	1.48	0.03	72.4	0.6	16	9	75

9.4 WATER SAMPLE ANALYSIS FOR IRRIGATION PURPOSES

Water for irrigation purposes are drawn directly from the Nzhelele Dam irrigation scheme. Seven samples were taken by WSM Leshika on the Mutamba River and two extra samples for the Makhado Mine monitoring report (Table 8 and 9, Surface water report). According to the surface water report, Sample SMon-13 reflects the water quality of the Nzhelele Dam. Although pH is high and there are slightly elevated levels of Chloride, it falls within the acceptable criteria for irrigation water. The quality of this water sample does not pose any limitation to irrigation or crop production.

Forty nine water samples were taken by the WSM Leshika team for analysis throughout the area. The positions and indication of water quality of the samples are illustrated in Figure 14. Table 10 is a copy of the water analysis results, analysed for agricultural and irrigation purposes only.

There are various water quality parameters but from an irrigation standpoint the chemical aspect (i.e., dissolved salts) is the most important. The following results are usually reported in testing irrigation water: electrical conductivity (EC), sodium adsorption ratio (SAR), pH, cations (Ca^{2+}, Mg^{2+}, K^{+} and Na^{+}), anions (CO_3^{2-}, HCO^{3-} SO_4^{2-} and Cl^{-}), salinity hazard and boron. In addition NO_3, micronutrients (Zn, Cu, Fe and Mn) as well as Ni, Pb, Cd, and As may be reported. The chemical analyses of different water sources within the Generaal Project are summarized in Table 10. Table 11 discusses the actual measured components in relation to the irrigation of crops and not for drinking water or for animal health.

Table 10: Water analysis report (from WSM Leshika)

Borehole	Longitude	Lattitude	pH	EC	TDS	NO_3_N	F	SO_4	Cl	Ca	Mg	Na
EKL-15	29.89628	-22.80043	7.8	142	832	3.0	0.5	11	151	33	46	143
Mon-18	29.91695	-22.79710	8.6	150	932	5.6	0.6	41	196	26	40	174
Mon-18	29.91662	-22.79688	8.7	140	862	0.2	0.6	39	184	54	59	212
TAN-1	29.91662	-22.79688	8.4	141	1093	3.1	0.6	144	294	16	147	242
Mon-2	29.94036	-22.79435	6.4	4020	25663	4.4	0.9	4103	8350	687	1248	5742
Mon-2	29.94036	-22.79435	7.1	3053	21282	0.2	0.8	1560	9273	1224	1062	5603
EKL-16	29.91364	-22.78453	7.4	85	524	0.6	0.2	27	121	36	22	74
BOAS -1	29.96751	-22.76368	6.7	135	984	0.0	0.5	62	186	165	107	110
PHAN-1	29.97235	-22.76112	7.6	93	612	13.0	0.5	48	53	117	61	31
RIS-5	29.89881	-22.75325	8.0	498	3072	1.7	0.5	130	1236	143	200	677
RIS-6	29.88948	-22.75306	7.7	415	2562	1.2	0.7	103	1083	128	189	501
RIS-2	29.89845	-22.74623	7.8	441	2802	2.9	0.6	240	1036	103	198	632
RIS-4	29.91376	-22.74595	7.7	369	2288	4.6	0.6	130	748	58	146	591
PHAN-2	29.96329	-22.74594	7.6	80	444	4.3	0.2	6	35	66	49	43
RIS-1	29.89857	-22.74511	7.4	782	4720	0.0	0.5	76	2282	190	370	988
PHAN-3	29.97591	-22.74504	7.2	90	548	5.3	0.2	10	40	62	62	53
PHAN-3	29.97952	-22.74504	7.4	81	490	5.8	0.2	10	36	57	54	42
BF-4	29.98260	-22.74096	7.3	72	461	0.5	0.4	28	62	42	43	44
FANI-2	29.93370	-22.73964	7.2	525	3360	3.0	0.5	157	0	122	235	614
FANI-1	29.92688	-22.73953	7.7	201	1290	0.2	3.7	5	380	8	9	390
RIS-3	29.90819	-22.73575	7.4	312	2022	2.2	1.2	176	630	123	185	334
BF-2	29.97116	-22.73239	6.9	773	4960	0.8	0.8	185	0	237	372	778
Nak-4	30.01402	-22.72389	7.5	276	1662	3.4	3.7	159	442	61	95	421
BF-1	29.99015	-22.72278	7.5	139	898	0.7	3.1	157	181	56	53	159
Nak-3	30.01604	-22.72240	7.4	331	1986	0.2	3.0	170	519	83	124	529
Nak-2	30.01414	-22.71575	7.2	242	1452	7.7	2.3	138	346	91	108	274
WILDG-1	29.96442	-22.71032	7.4	198	1270	10.0	1.3	113	195	118	111	167
Mon-13	30.04590	-22.70397	8.6	100	580	0.5	1.6	45	98	58	61	109
Mon-13	30.04590	-22.70397	7.8	108	612	0.5	1.8	49	141	65	63	115
Mon-24	30.02608	-22.69270	7.4	150	932	8.1	1.0	57	120	95	98	109
Adale-1	30.14450	-22.64907	7.0	56	350	2.6	0.3	23	72	31	25	46
TSHIP-2	30.17218	-22.64397	8.4	89	574	0.8	0.6	13	67	21	34	109
Adale-16	30.14410	-22.64042	7.8	341	2158	0.2	1.1	338	703	151	169	381
Adale-4	30.13532	-22.63646	8.1	215	1448	60.0	0.8	112	277	96	130	203
Adale-6	30.14197	-22.63600	8.5	299	1908	23.0	1.4	274	365	40	89	315
H18-0006	30.16540	-22.63500	7.9	294	1718	0.2	0.4	110	552	34	16	511
TSHIP-4	30.19217	-22.62775	8.1	252	1510	14.0	0.4	151	489	34	65	336
Adale-7	30.13469	-22.62129	7.6	159	964	8.2	0.6	93	245	98	69	163
Ter-1	30.12417	-22.66993	7.7	191	1243	8.2	1.4	79	218	60	75	273
Kran-1	30.06825	-22.69962	7.9	104	676	1.6	2.8	105	111	25	12	194
Jap-1	29.97318	-22.69263	7.1	143	929	9.2	1.8	46	63	77	100	121
H29-0011	30.22987	-22.72108	7.2	179	1165	29.8	0.2	50	224	141	70	154
Ojan-1	29.93187	-22.69823	7.6	232	1507	18.5	2.4	98	236	75	110	301
H25-0010	30.17602	-22.70605	7.3	246	1601	64.0	0.3	127	333	161	144	150
Vrie-1	29.82327	-22.68775	7.3	161	1045	6.3	2.1	64	137	57	80	189
Ter-3	30.16160	-22.67683	7.9	116	757	1.4	0.6	45	90	73	71	90
Riet-2	30.05610	-22.69300	7.5	298	1936	3.2	1.7	317	525	68	98	440
MTS-1	29.97010	-22.33377	7.9	154	998	<1,4	2.8	18	241	28	37	256
Sdrif-15	30.07285	-22.69223	7.7	124	804	3.4	4.2	147	146	53	30	175

Borehole	Al	As	B	Cd	Co	Cr	Cu	Fe	Mn	Mo	Ni	Pb	Se	V	Zn
EKL-15	0.10	0.13	0.25	0.01	0.025	0	0.025	0.0	0.14	0.025	0.025	0.02	0.020	0.036	0.025
Mon-18	0.1	0.01	0.22	0.01	0.025	0	0.025	0.0	0.03	0.025	0.025	0.02	0.020	0.05	0.025
Mon-18	0.13	0.01	0.36	0.01	0.025	0	0.025	0.0	0.03	0.025	0.025	0.02	0.020	0.03	0.025
TAN-1		0.00	0.00		0.000		0.000	0.0	0.00				0.000		0.000
Mon-2		0.00	0.00		0.000		0.000	0.2	0.08				0.000		0.000
Mon-2	0.13	0.01	0.98	0.01	0.025	0	0.025	2.4	1.40	0.025	0.025	0.02	0.020	0.025	0.025
EKL-16	0.14	0.01	0.16	0.01	0.025	0	0.083	0.9	0.60	0.025	0.025	0.02	0.020	0.025	0.196
BOAS -1		0.00	0.00		0.000		0.000	0.0	0.00				0.000		0.000
PHAN-1	0.1	0.01	0.10	0.01	0.025	0	0.025	0.0	0.03	0.025	0.025	0.02	0.020	0.032	0.025
RIS-5	0.13	0.00	0.70	<0.005	0.000	<0.025	0.000	0.1	0.00	<0.025	<0.025	<0.020	0.000	<0.025	0.000
RIS-6	0.13	0.00	0.47	<0.005	0.000	<0.025	0.000	0.1	0.07	<0.025	<0.025	<0.020	0.000	<0.025	0.054
RIS-2	0.12	0.00	0.58	<0.005	0.000	<0.025	0.000	0.0	0.00	<0.025	<0.025	<0.020	0.000	<0.025	0.290
RIS-4	<0.100	0.00	0.76	<0.005	0.000	<0.025	0.000	0.0	0.00	<0.025	<0.025	<0.020	0.000	<0.025	0.000
PHAN-2	0.1	0.01	0.16	0.01	0.025	0	0.025	0.0	0.03	0.025	0.025	0.02	0.020	0.026	0.025
RIS-1	0.14	0.00	0.57	<0.005	0.000	<0.025	0.000	1.5	0.93	<0.025	<0.025	<0.020	0.000	<0.025	0.000
PHAN-3	0.11	0.02	0.17	0.01	0.025	0	0.025	0.1	0.03	0.025	0.025	0.02	0.020	0.025	0.027
PHAN-3	0.1	0.01	0.16	0.01	0.025	0	0.092	0.2	0.03	0.025	0.025	0.02	0.020	0.04	0.096
BF-4	0.1	0.01	0.19	0.01	0.025	0	0.025	0.6	0.27	0.044	0.025	0.02	0.020	0.025	0.025
FANI-2	0.1	0.01	0.74	0.01	0.025	0	0.025	0.0	0.03	0.025	0.025	0.02	0.020	0.037	0.025
FANI-1	0.2	0.01	0.78	0.01	0.025	0	0.025	2.8	0.04	0.025	0.025	0.02	0.020	0.025	0.102
RIS-3	0.14	0.00	0.86	<0.005	0.000	<0.025	0.000	1.7	0.03	<0.025	<0.025	<0.020	0.000	<0.025	1.010
BF-2	1.65	0.01	0.64	0.01	0.025	0	0.037	12.0	1.54	0.025	0.025	0.02	0.020	0.025	0.319
Nak-4	0.12	0.01	0.69	0.01	0.025	0	0.025	0.1	0.03	0.025	0.025	0.02	0.020	0.032	0.036
BF-1	0.1	0.01	0.35	0.01	0.025	0	0.025	8.0	0.05	0.025	0.025	0.02	0.020	0.025	0.025
Nak-3	0.49	0.01	0.97	0.01	0.025	0	0.025	216.0	0.91	0.025	0.071	0.047	0.034	0.177	1.550
Nak-2	0.1	0.01	0.50	0.01	0.025	0	0.025	0.0	0.03	0.025	0.025	0.02	0.020	0.025	0.025
WILDG-1	0.1	0.01	0.35	0.01	0.025	0	0.027	0.0	0.03	0.035	0.025	0.02	0.020	0.025	0.073
Mon-13	0.59	0.01	0.37	0.01	0.025	0	0.025	0.1	0.07	0.06	0.025	0.02	0.020	0.025	0.025
Mon-13	0.1	0.01	0.41	0.01	0.025	0	0.025	0.1	0.34	0.025	0.025	0.02	0.020	0.025	0.025
Mon-24	2.81	0.03	0.29	0.01	0.025	0	0.025	13.0	0.42	0.025	0.025	0.02	0.020	0.025	2.210
Adale-1	0.18	0.01	0.18	0.01	0.025	0	0.109	0.3	0.03	0.025	0.025	0.02	0.020	0.025	0.046
TSHIP-2	0.1	0.01	0.29	0.01	0.025	0	0.025	0.1	0.03	0.025	0.025	0.02	0.020	0.031	0.157
Adale-16	0.16	0.01	0.50	0.01	0.025	0	0.025	0.6	0.14	0.025	0.025	0.02	0.020	0.025	0.062
Adale-4	0.15	0.01	1.18	0.01	0.025	0	0.025	0.1	0.03	0.025	0.025	0.02	0.020	0.086	0.025
Adale-6	0.15	0.01	1.42	0.01	0.025	0	0.025	0.2	0.03	0.025	0.025	0.02	0.020	0.052	0.025
H18-0006	0.1	0.01	0.96	0.01	0.025	0	0.025	0.1	0.03	0.025	0.025	0.02	0.020	0.025	0.157
TSHIP-4	0.1	0.01	0.50	0.01	0.025	0	0.025	0.1	0.03	0.025	0.025	0.02	0.020	0.025	0.087
Adale-7	0.18	0.01	0.52	0.01	0.025	0	0.025	2.8	0.07	0.025	0.025	0.02	0.020	0.056	0.093
Ter-1	<0,01	<0,03	0.39	<0,01	<0,01	<0,01	<0,01	0.0	0.30	<0,05	<0,01	<0,09	<0,02	0.03	0.35
Kran-1	<0,01	<0,03	0.28	<0,01	<0,01	<0,01	<0,01	0.0	<0,01	<0,05	<0,01	<0,09	<0,02	<0,01	<0,01
Jap-1	<0,01	<0,03	0.21	<0,01	<0,01	<0,01	<0,01	0.0	0.20	<0,05	<0,01	<0,09	<0,02	0.03	1.00
H29-0011	<0,01	<0,03	0.31	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,05	<0,01	<0,09	0.03	0.02	0.08
Ojan-1	<0,01	<0,03	0.71	<0,01	<0,01	<0,01	0.02	0.0	<0,01	<0,05	<0,01	<0,09	<0,02	0.03	0.02
H25-0010	<0,01	<0,03	0.25	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,05	<0,01	<0,09	0.02	0.05	0.06
Vrie-1	<0,01	<0,03	0.51	<0,01	<0,01	<0,01	<0,01	0.0	<0,01	<0,05	<0,01	<0,09	<0,02	0.05	<0,01
Ter-3	<0,01	<0,03	0.22	<0,01	<0,01	<0,01	<0,01	0.0	<0,01	<0,05	<0,01	<0,09	0.02	<0,01	0.01
Riet-2	<0,01	<0,03	0.75	<0,01	<0,01	<0,01	<0,01	<0,01	0.02	<0,05	<0,01	<0,09	<0,02	0.02	0.03
MTS-1	<0,01	<0,03	0.33	<0,01	<0,01	<0,01	<0,01	0.0	0.05	<0,05	<0,01	<0,09	0.03	<0,01	0.01
Sdrif-15	<0,01	<0,03	0.24	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,05	<0,01	<0,09	<0,02	0.01	0.01

Table 11: The severity criteria for the different components of irrigation water

Species	Severity			Issue	Mitigation
	Not a problem	Increasing problem	Severe problem		
pH	6.5– 8.0		<6 or >8	Influence availability of plant nutrients. Use as indicator that a problem can exist. Alkaline water can indicate water high in CO_3 and HCO_3 and or salinity. pH <5.5 or >8.5 can cause corrosion of pipes or equipment.	Apply soil acidifiers to maintain soil pH in the desired range when irrigating with high pH water.
EC (dS/m)	0.5– 0.75	0.75 – 3.0	<0.5 or >3	Use EC as the initial identifying that a problem exists. Further evaluation is needed to determine if the problem is TDS, Na and or CO_3 and HCO_3.	Apply surplus irrigation water (in addition to crop water requirements) in order to leach accumulating salt out of the soil and/or accept a reduced crop yield; and/or switch to crops which are more salt-tolerant; and/or plant annual crops at a higher density and/or switch to a higher frequency irrigation application. use irrigation only to supplement rainfall, that is, do not practice full-scale irrigation.
TDS (mg/l)	< 500	500–2000	>2000	High salinity can result in salt accumulation in fine textured soils, making it hard for roots to adsorb water. Must determine if dominated by sodium.	Apply surplus irrigation water (in addition to crop water requirements) in order to leach accumulating salt out of the soil and/or accept a reduced crop yield; and/or switch to crops which are more salt-tolerant; and/or plant annual crops at a higher density and/or switch to a higher frequency irrigation application. use irrigation only to supplement rainfall, that is, do not practice full-scale irrigation.
NO_3^- (mg/l)	<50	50 – 100	>100	High concentrations can cause succulent tissue that is not as resource efficient and more susceptible to	reduce nitrogen fertilizer application by the amount added with

				some pests. Runoff can cause eutrophication in receiving waters.	irrigation water; and/or switch to crops with a high nitrogen requirement; and/or limit leaching as far as possible to reduce the likelihood of ground water contamination; control algae growth in irrigation structures chemically with copper sulphate; remove nuisance algae and water plants from irrigation water with screens and filters.
F^- (mg/l)	< 2.0	2.0 – 15.0	>15.0	The most serious effect of fluoride is usually not its effect on plant growth, but rather its effect on animals and humans that consume plants that have accumulated fluoride.	apply agricultural lime in order to raise (or maintain) soil pH to neutral to slightly alkaline and/or switch to a crop that is more tolerant to F; apply agricultural gypsum to raise the soil calcium content and promote the formation of F which has a relatively low solubility.
SO_4^{2-} (mg/l)	<100	100 - 200	>200	If calcium is present scale can form. As part of salinity, can reduce growth and or cause plant injury.	Scaling due to hard water may be alleviated by lowering the pH. Scale is extremely difficult to remove and even with the use of the stabilised acid wash procedure, removal is seldom effective.
Cl^- (mg/l)	< 70	70 - 300	>300	Mobile in the soil, Cl can be taken up by roots and accumulate in leaves causing toxicity.	Accept a reduced crop yield or quality; and/or switch to crops that are more tolerant to chloride.
Ca^{2+} (mg/l) For soil and water ion hazard	< 25	25 – 250	>250	Binds with CO_3 and HCO_3 to form lime deposits, contributes to "hard water" and salinity.	Accept a reduced crop yield or quality.

For foliar injury	<60	60 - 100	>100		
Mg^{2+} (mg/l)	< 20	20 - 40	>40	Binds with CO_3 and HCO_3 to form lime deposits, contributes to "hard water" and salinity.	Switch to an irrigation method that does not wet the leaves; or accept a reduced crop yield or quality; and/or switch to crops with a lower foliar adsorption rate
Na^+ (mg/l) For soil and water ion hazard For foliar injury	<70 <70	70 - 200	> 200 >70	High concentration can speed up corrosion by other elements. Can also burn foliage. Can negatively influence soil structure. Must evaluate with SAR and EC.	Switch to an irrigation method that does not wet the leaves; or accept a reduced crop yield or quality; and/or switch to crops that are more tolerant to sodium; and/or switch to crops with a lower foliar adsorption rate; and/or ameliorate the water and/or soil with plant nutrients such as Ca, Mg and K to overcome plant nutritional imbalances induced by the excess sodium
Zn (mg/l)	<2.0		>2.0	Not usually a problem, can give water a milky appearance. When low pH water is in contact with copper-zinc alloys used in plumbing, zinc from corrosion is released.	Apply agricultural lime in order to raise (or maintain) soil pH to neutral to slightly alkaline; and/or apply huge quantities of organic material; and/or switch to a crop that is more tolerant to zinc.
Cu (mg/l)	<0.2	0.2-5.0	>5.0	Not usually a problem, can cause staining and have a corrosive effect. Toxicity can occur in some plants at concentrations <1.0 mg/l.	apply agricultural lime in order to raise (or maintain) soil pH to neutral to slightly alkaline; and/or switch to a crop that is more tolerant to Cu; apply ample phosphate fertilisers or iron salts; the addition of either has been reported to reduce Cu toxicity.
Mn (mg/l)	<0.2		>0.2	Not usually a problem, excessive Mn turns water greyish/black, can cause coatings on leaves and subsequently	Apply agricultural lime, in order to raise or maintain soil pH to

				reducing photosynthesis.	neutral to slightly alkaline; and/or maintain the aeration status of the soil to ensure oxidising conditions; and/or switch to a crop that is more tolerant to Mn.
Fe (mg/l)	<0.3	0.3 – 5.0	>5.0	In the presence of oxygen (water or air) rust form. If salt is present, the metal will rust faster. The rust can cause reddish-brown staining and or flake off and clog nozzles, filters and lines. Iron also complexes with organic material and bacteria which can cause slimes. When >5.0 mg/l, coatings form on leave surfaces and subsequently reduce photosynthesis.	Apply agricultural lime in order to raise (or maintain) soil pH to neutral to slightly alkaline; and/or ensure that soil is well aerated and not waterlogged; and/or switch to an irrigation system that does not wet plant leaves or marketable products.
B (mg/l)	<1.0	1.0 – 2.0	>2.0	Needed in small amounts by plants. When in excess it is very toxic. Plant sensitivity widely ranges.	Accept a reduced crop yield; and/or switch to crops which are more boron-tolerant; and/or apply extra nitrogen to stimulate vegetative growth in cases where boron toxicity induced leaf drop reduces the photosynthetic capability of a tree crop.
Al (mg/l)	<5.0	5.0 - 20	>20	Aluminium is not a plant nutrient. Toxicity of aluminium to plants has been reported for both acid and alkaline conditions. It is, however, mostly associated with low pH values (less than 5.5) in natural soils.	Ensure that soil is well aerated and not waterlogged Switch to crops that are more tolerant of aluminium.
As (mg/l)	<0.1	0.1 – 2.0	>2.0	Although very low concentrations of arsenic stimulate plant growth, it is not an essential plant nutrient and crop yields are depressed at high concentrations. The main effect of arsenic in plants appears to be the destruction of chlorophyll in the foliage, as a consequence of inhibition of reductase enzymes. Since arsenic is toxic to humans, consumption of edible plant parts containing accumulated arsenic is dangerous.	The only effective management practice for soils with toxic concentrations of arsenic is to switch to more tolerant crops.
Cd (mg/l)	<0.01	0.01 – 0.05	>0.05	Cadmium is readily taken up by plants, even though it is not an essential plant nutrient. Due to its chemical similarity to zinc (an essential plant nutrient), cadmium can readily interfere with	Apply agricultural lime in order to raise (or maintain) soil pH to neutral to slightly alkaline; and/or

				some plant metabolic processes and is therefore toxic to many plants. Plants, however, do vary in their sensitivity to cadmium. The regular consumption of cadmium-enriched foods over decades results in the accumulation of cadmium to concentrations that are detrimental to human health.	switch to a crop that is more tolerant to Cd; and/or ensure an adequate supply of Zn, Mn, and Cu - the uptake of Cd is reduced by an adequate supply of these elements.
Co (mg/l)	<0.05	0.05 – 5.0	>5.0	Cobalt is not generally considered a plant nutrient, but appears to be essential for some plant species. The occurrence of cobalt toxicity is rare under field conditions, presumably because it is strongly sorbed by soil.	Apply agricultural lime in order to raise (or maintain) soil pH to neutral to slightly alkaline; and/or switch to a crop that is more tolerant to Co.
Cr (mg/l)	<0.1	0.1 – 1.0	>1.0	Chromium has no known plant physiological function and is not an essential plant nutrient but, at low concentrations it has been found to have a beneficial effect on plant growth. At high concentrations, chromium becomes toxic to plant growth.	Apply agricultural lime in order to raise (or maintain) soil pH to neutral to slightly alkaline; and/or switch to a crop that is more tolerant to Cr.
Mo (mg/l)	<0.01	0.01 – 0.05	>0.05	Molybdenum in low concentrations is an essential plant micro-nutrient, and plants can take up relatively large amounts of molybdenum without any apparent ill effect.	Switch to a crop that is less absorbent of molybdenum; and/or acidify the soil switch to crops that are not used as forage for livestock.
Ni (mg/l)	<0.2	0.2 – 2.0	>2.0	Nickel can be translocated from soils through the human and animal food chain. It is not considered to be an essential plant nutrient.	apply agricultural lime in order to raise (or maintain) soil pH to neutral to slightly alkaline conditions; and/or switch to a crop that is more tolerant to Ni.
Pb (mg/l)	<0.2	0.2 – 2.0	>2.0	Compared to other trace elements, lead has a fairly low phytotoxicity and is seldom encountered in the soil solution because lead is strongly sorbed by soil. Plants are nonetheless capable of accumulating lead at concentrations that are potentially hazardous to humans and livestock, for example, potatoes, lettuce and hay.	apply agricultural lime in order to raise (or maintain) soil pH to neutral to slightly alkaline; and/or switch to a crop that is more tolerant to lead.
Se (mg/l)	<0.02	0.02 – 0.05	>0.05	Plants take up relatively large amounts of selenium without apparent adverse effects. Of more concern is the toxicity of selenium to animals eating plants containing too much selenium.	Leach excess selenium from the soil when selenium is in the selenate form; and/or apply sulphate to the soil to inhibit uptake of selenium; and/or

					switch to a crop that is less absorbent of selenium.
V (mg/l)	<0.1	0.1 – 1.0	>1.0	Vanadium is not required for plant growth. Vanadium interferes with the uptake of essential plant nutrients such as calcium, copper, iron, manganese and phosphorus.	Apply lime in order to raise (or maintain) soil pH to neutral to slightly alkaline conditions; and/or switch to a crop that is more tolerant to vanadium.

Infiltration can decrease under certain salinity and Na conditions. The EC (dS/m) and the SAR values should be match up to Table 11 to determine if a problem may exits. Divalent cations such as Ca and Mg act as bridges to bind soil particles together forming soil aggregates. When there are few divalent cations, soil porosity is low with few aggregates and water infiltration is difficult (e.g. EC=0.3 dS/m and SAR is between 0 and 3). Sodium a monovalent cation does not form bridges between soil particles thus limiting aggregate formation. When Na dominates in irrigation water the soil particles disperse and infiltration is low. When Na is present in irrigation water but divalent cations dominate or the EC is high the soil form aggregates and infiltration is high.

Table 12: Outline of the problems encountered with water quality for irrigation purposes

Attribute	Samples with a severe problem
pH	Mon-18,TAN-1,Mon-13, TSHIP-2, TSHIP-4, Adale4, Adale-6,
EC	Mon-2, RIS-5,RIS-6,RIS-2, RIS-4,RIS-1,FANI-2,RIS-3,BF-2,Nak-3, Adal1-16
TDS	Mon-2, RIS-5,RIS-6,RIS-2, RIS-4,RIS-1,FANI-2,RIS-3,BF-2, Adal1-16
NO3_N_	None
F	None
SO_4	Mon-2,RIS-2,Adale-16,Adale-6,Riet-2
Cl	Mon-2,RIS-5,RIS-6,RIS-2,RIS-4,RIS-1,RIS-3,FANI-1,Nak-4,Nak-3,Nak-2, Adale-16,Adale-6,H18-006,TSHIP-4,H24-0010,Riet-2
Ca	Mon-2
Mg	All except: EKL-16,FANI-1,Adale-1,TSHIP-2,H18-0006,Kran-1,MTS-1,Sdrif-15
Na	Mon-18,TAN1,Mon2,RIS-5,RIS-6,RIS-2,RIS4,RIS-1,FANI-2,FANI1,RIS3,BF-2,Nak-4,Nak-3,Nak-2,Adale-16,Adale-4,Adale-6,H18-0006,TSHIP-4,Ter-1,Ojan-1,Riet-2,MTS-1
Al	None
As	None
B	None
Cd	None
Co	None
Cr	None
Cu	None
Fe	BF-2,BF-1,Nak-3,Mon-24
Mn	Mon-2,EKL-16,RIS-1,BF-4,BF-2,Nak-3,Mon-13,Mon-24,Ter-1
Mo	Mon-13
Ni	None
Pb	None
Se	None
V	None
Zn	Mon-24

The SAR of the water samples with a high sodium content (> 200mg/l) were calculated and are summarized in Table 13.

Table 13: The SAR and EC values of all water samples with sodium content higher than 200 mg/l.

Sample	SAR	EC	Infiltration problem
Mon-18	5	1.4	Unlikely
TAN-1	4	1.4	Unlikely
Mon-2	30	40.2	Unlikely
Mon-2	28	30.5	Unlikely
RIS-5	9	5.0	Unlikely
RIS-6	7	4.2	Unlikely
RIS-2	8	4.4	Unlikely
RIS-4	9	3.7	Unlikely
RIS-1	10	7.8	Unlikely
FANI-2	7	5.3	Unlikely
FANI-1	22	2.0	Unlikely
RIS-3	4	3.1	Likely
BF-2	7	7.7	Unlikely
Nak-4	8	2.8	Unlikely
Nak-3	9	3.3	Unlikely
Nak-2	5	2.4	Unlikely
Adale-16	5	3.4	Unlikely
Adale-4	3	2.2	Unlikely
Adale-6	6	3.0	Unlikely
H18-0006	18	2.9	Unlikely
TSHIP-4	8	2.5	Unlikely
Ter-1	6	1.9	Unlikely
Ojan-1	5	2.3	Unlikely
MTS-1	7	1.5	Moderate

Table 14: Infiltration based on the SAR and EC of irrigation water

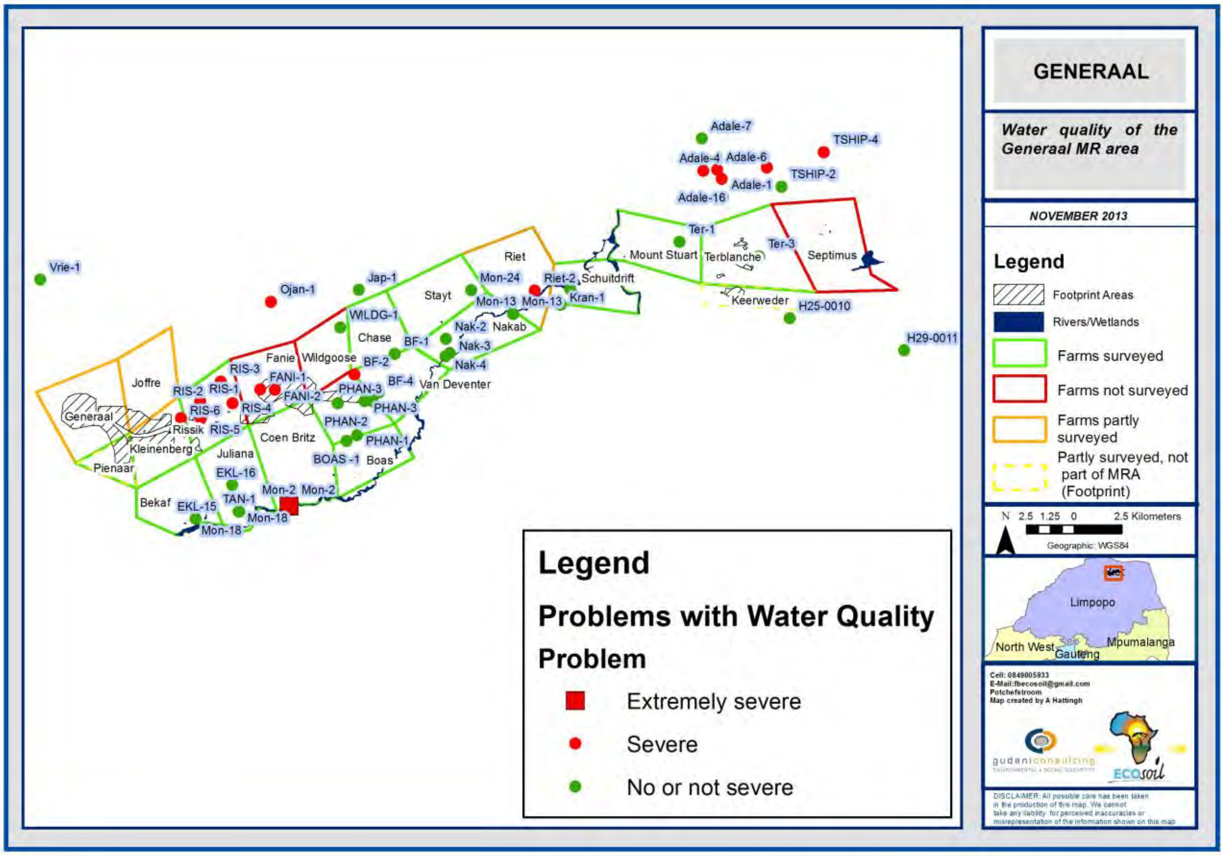
SAR of irrigation water	Infiltration problem unlikely when EC is more than	Infiltration problem likely when EC is less than
0 to 3	0.7	0.4
3 to 6	1.2	0.3
6 to 12	1.9	0.5
12 to 20	2.9	1.3
20 to 40	5.0	2.9

A summary of the water quality problems for irrigation purposes of each water sample is given in Table 12. The quality of boreholes varies throughout the study area. The quality of water of Mon 2 is extremely poor. This sample was taken on the farm Coen Britz, on the southern boundary adjacent to the Mutamba River as can be seen in Figure 14. The following water quality parameters are problematic in the water samples:

- Sodium (Na) levels: 24 samples of the 49 have high levels of sodium, which can create various soil physical problems e.g. poor infiltration, dispersion and inhibition of plant growth.
- Chloride (Cl) levels: 19 samples of the 49 have high levels of Chloride, which is detrimental to certain crops.
- Other combined problems are high pH values, high electrical conductivity (EC) values, high total dissolvable solids (TDS), high Magnesium (Mg) and Manganese (Mn) values, creating imbalances in nutrient uptake and soil fertility.

Evaluation of water quality should also take the amounts and availability of water into consideration to determine the potential for irrigation purposes. This aspect is not covered in this report.

Figure 14: Position and indication of water quality of water samples



9.4.1 LAND CAPABILITY ASSESSMENT

The land capability according to the Chamber of Mines 1991 classification of the surveyed area is presented in Figure 15 and is summarised per farm in Table 15.

- Wetlands are defined as: "Land with organic soils or supporting hygrophilous vegetation where soil and vegetation processes are water determined". In this study area the following criteria was used:

    - Riparian zones were not delineated, and only wetland soil parameters per definition were used.
    - Small farm dams and pans that fell between two observation points (based on the grid size in the ToR's) were not mapped.

- Footprints on the surveyed areas are generally covered by soils classified with a mixture of arable, wilderness and grazing capability.
- The farms Generaal, Pienaar and Kleinenberg, as well as on the farms Rissik and the northern parts of Bekaf have deep soils. Deep soils are also found on the south-western parts of Chase and north western parts of Van Deventer and the areas surrounding the river on the farms Riet and Schuitdrift. According to the Chamber of Mines (1991) classification (Table 3) these deep soils can be regarded as arable, especially under irrigation. According to the agricultural classification (as is outlined in Table 4 and 5, Klingebiel & Montgomery, 1961) these soils are classified as classes III to IV (Table 16) and the restriction being the low rainfall and sandy conditions.

Figure 15: Land capability of the surveyed area

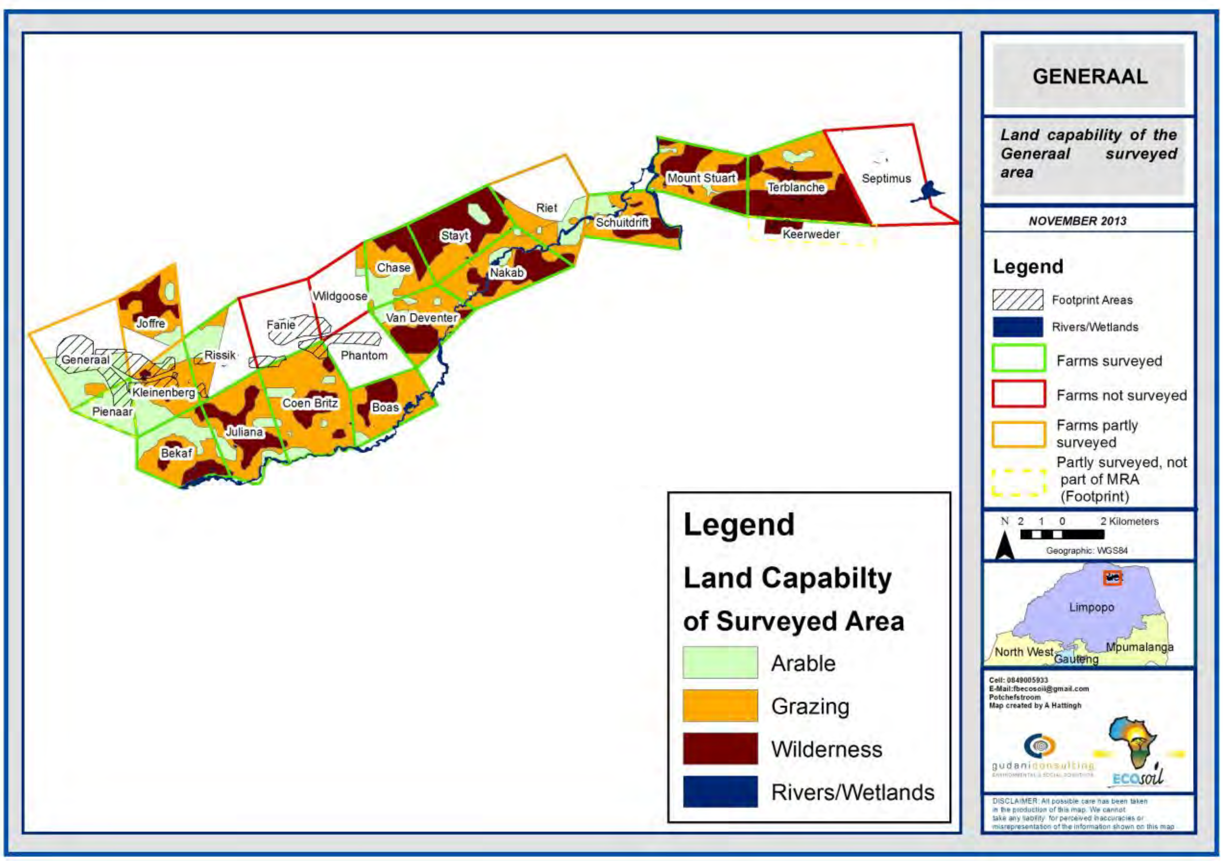


Table 15: Land capability classes and areas of each farm respectively for the study area

Farm name	Area (Ha)	Not surveyed	Arable	Grazing	Wilderness	Wetland
Bekaf	1043		308.9	475.6	250.0	8.3
Boas	856		35.4	566.9	217.7	35.9
Chase	848		216.8	395.5	235.8	
Coen Britz	1673		151.8	1234.3	277.8	9.5
Fanie	1044	1044				
Generaal	1461	786.4	623.5	51.6		
Joffre	1015	266.4	104.6	358.2	285.3	
Juliana	1225	17.8	161.2	602.0	422.6	21.7
Kleinenberg	883		375.7	467.8	39.4	
Mount Stuart	1137		58.0	505.3	562.0	11.8
Nakab	1156		77.6	593.5	442.7	41.8
Phantom	870	870				
Pienaar	403		399.5	3.3		
Riet	1347	766.4	189.1	317.1	44.6	29.9
Rissik	999	555.1	212.3	231.8		
Schuitdrift	867		125.8	442.0	233.9	65.3
Septimus	1676	1676				
Stayt	1186		63.5	308.5	813.8	
Terblanche	1727		58.3	648.2	1020.1	
Van Deventer	957		120.0	526.6	290.5	20.1
Wildgoose	734	734				
Keerweder	127				127.0	
Total	**23234**	**6715**	**3282**	**7728**	**5263**	**244**
% of Area	**100**	**28.9**	**14.1**	**33.3**	**22.7**	**1.1**

9.4.2 AGRICULTURAL POTENTIAL ASSESMENT

For purposes of international and national technology transfer and simplicity, the methodology was aimed at reflecting the classic concepts of land capability, as established by Klingebiel and Montgomery (1961) as far as possible. These concepts were to be brought under parameters suited to South African conditions and the local availability of data.

External factors like climate, topography, erosion factors, surface rock and water quality parameters are brought in consideration to determine the present agricultural potential.

- The soils of Group 1-2 are classified as a class III potential. The biggest restraint being texture, percolation and soil fertility. These soils can be irrigated. Soil fertility problems can be overcome with chemical and biological fertilizers and management practices.
- The soils of Group 3 are classified as a class III-IV. The biggest restraint being texture, percolation and erosion potential.
- The soils of Group 4 are classified as a class V-VI potential. The biggest restraint being shallow soils, erosion and surface rock.
- The soils of Group 5 are classified as a class IV potential. The biggest restraint being slow infiltration rates, erosion and surface rock.
- The soils of Group 6 are classified as a class V potential. The biggest restraint being slow infiltration rates, soil structure and poor drainage.
- The soils of Group 7 are classified as a class VII potential. The biggest restraint being surface rock, shallow soils.
- The soils of Group 8 are wetland areas and classified as a class VIII potential.

Table 16: Agricultural Potential Classification of land capability classes according to agricultural classification system

Soil Management Unit	Soil Group 1	Soil Group 2	Soil Group 3	Soil Group 4	Soil Group 5	Soil Group 6	Soil Group 7	Soil Group 8
Soil Types	Red Apedal	Yellow Apedal	Neo Cutanic	Carbonate	Neo Carbonate	Pedo cutanic	Shallow rocky	Wetland
Soil depths cm	30-150	45-150	40-150	10-40	40-150	30-100	0-45	-
Average soil depth cm	100	86	90	18	89	61	21	-
Limiting Factors	Texture, Water-holding capacity	Texture, Water-holding capacity	Erosion, Depth, Surface rock	Surface Rock, Erosion	Surface Rock, Erosion	Structure, Erosion, Wetness	Rock, Depth	Water-logging
External Factors	Climate, Water Quality	Climate, Water Quality	Climate, Water Quality	Climate, Water Quality	Climate, Water Quality	Climate, Water Quality	Climate, Water Quality	Climate, Water Quality
Land capability	Arable, crop production	Arable crop production	Arable / Grazing	Grazing / Wilderness	Wilderness / Grazing	Grazing	Wilderness	Wetland
Agricultural potential	Low to medium	Low to medium	Low to medium	Marginal	Marginal	Low	Marginal	Marginal
Agricultural Classification	III	III	III-IV	VI	IV-V	VI	VII	VIII

10. SUMMARY OF THE IMPACT OF THE MINING DEVELOPMENT ON AGRICULTURAL POTENTIAL AND LAND CAPABILITY

Table 17: Summary of the impact of mining on agricultural potential and land capability

Impact	**Loss of agricultural potential and land capability**		
	Footprint area		**MRA**
	Without mitigation	With mitigation	
Extent	High	High	Low
Duration	Permanent	Permanent	Low
Magnitude	High	High	Low
Probability	Highly probable	Highly probable	Low
Significance	High	High	Low-medium
Status (positive or negative)	Negative	Negative	Negative
Reversibility	Medium	Medium	Medium
Irreplaceable loss of resources	Yes	Yes	No
Can impacts be mitigated	No	No	Yes
* The agricultural potential of the area is low, but the loss of agricultural land stretches far beyond the operational mining processes.			
* Due to low clay contents, wind erosion can become a problem if soils are not permanently covered with vegetation. Soil erosion is a strong possibility due to increased surface run-off and occasional high intensity rain occurrences in areas with higher clay contents. Erosion control and adequate management is needed.			
* Loss of agricultural land is a long term loss. There are no mitigation measures that can combat this type of loss.			

11. CONCLUSIONS OF SOILS ASSESSMENT

- Approximately 16519ha of the total project area was surveyed. Access was denied on the remainder of the proposed study area.
- Different soil properties of the surveyed areas are illustrated in Figures 11 to 13.
- Approximately (324ha) in the project area are presently under cultivation (156ha dry land and 168ha irrigated).
- Rainfall is in general too low for rain-fed crop production, however areas near the hills have higher rainfall (even 500 to 639mm as indicated in Figure 7). As a result of low rainfall, high temperatures (high evapotranspiration), susceptibility to compaction, present erosion and erodibility of the soils in the area, the soils are not always optimal for rain fed crop production.

- Approximately 3282ha of the study area is deeper than 75cm and can be regarded as good for crop production when rainfall permits or when high quality water for irrigation is available.
- Almost the entire area has very low clay contents of between 2 and 10% in the topsoil, which makes it susceptible for wind erosion.
- The majority of area have soils with low Profile available water capacities (PAWC (<100mm). This confirms that suitability for irrigation is limited to the very deep soils on the south western portion of the study area. This suitability is dependent on the availability of sufficient good quality irrigation water sources.
- Water for irrigation purposes are drawn directly from the Nzhelele Dam irrigation scheme. According to the surface water report done by WSM Leshika (p30 Table 9), sample SMon-13 reflects the water quality of the Nzhelele Dam. Though pH is high and there are slightly elevated levels of Chloride, it falls within the acceptable criteria for irrigation water. The quality of this water sample does not pose any limitation to irrigation or crop production.
- Forty nine (49) water samples of boreholes throughout the study area were analysed for suitability for irrigation purposes. Boreholes are, however, not being used for irrigation purposes at present.

  Water quality for irrigation purposes varies across the project area.
  - Sodium (Na) levels: 24 samples of the 49 have high levels of sodium, which can create various soil physical problems e.g. poor infiltration, dispersion and inhibition of plant growth.
  - Chloride (Cl) levels: 19 samples of the 49 have high levels of Chloride, which is detrimental to certain crops.
  - Other combined problems are high pH values, high electrical conductivity (EC) values, high total dissolvable solids (TDS), high Magnesium (Mg) and Manganese (Mn) values, creating imbalances in nutrient uptake and soil fertility.
- Some of the water samples only have minor suitability constraints and can be used for irrigation if it is well managed. Water samples were taken during the winter and it

is recommended to make a continual assessment of water quality during the year, since it can change significantly during the year.

- Generalisations of the land capability of the areas not yet surveyed can be obtained from Figure 9.
- The land capability of the surveyed area is presented in Figure 15. From the differences between Figures 9 and 15 it can be seen that it is crucial to do a proper soil investigation on the farms not yet surveyed, in order to obtain a better and more accurate assessment of the land potential, especially on the footprint area.
- Footprint areas on the farms Fanie, Phantom Wildgoose and portions of Rissik, Joffre and Generaal were not surveyed, but from Figure 9 it can be concluded that large areas of the proposed footprint have arable soils.
- Shallow soils and surface rock are dominant in large areas. Areas classified for grazing have presently low basal grass cover and are dominated by Mopane shrub field and will be discussed in detail by the biodiversity report.
- Present land use is cattle and game farming, but carrying capacity is questionable due to poor soil fertility (erosion susceptibility, shallow soils, and surface rock) and poor climatic conditions.
- Table 15 presents the different categories and areas for the **surveyed farms** according to the Mining classification,:

    - Arable land 3282ha (14.1%)
    - Grazing areas 7728ha (33.3%)
    - Wilderness areas 3114ha (22.7%)
    - Wetland areas 244ha (1.1%)

  - Soils classified as arable land fall into classes III to IV according to the agricultural classification system.
  - Generally the soils are sandy and susceptible to wind erosion and should be permanently covered with vegetation to prevent wind erosion and top soil loss. Uncovered areas are also susceptible to water erosion in times of high intensity storms.

- The same restrictions and limitations discussed above apply for the footprint areas.
- Stripping and rehabilitation for the proposed mining operation will be discussed separately under point 15 and onwards.

12. RECOMMENDATIONS OF SOILS ASSESSMENT

Impacts on the environment must be minimized or limited on construction sites. The following is recommended if the area will be used for mining purposes:

- The areas not yet surveyed should be surveyed and analysed in more detail to determine the areas for soil potential
- Water quality should be monitored as an on-going process with high priority. High quality irrigation is present in some areas and should be kept in that state. If any changes are observed, the source of pollution should be determined and eliminated.
- If mining is considered in the area, specialists should be used to evaluate the erosion and other possible impacts during the entire mining process. The entire area should be vegetated throughout the entire duration of mining due to the possibility of wind erosion and relative dry conditions (low clay contents in the top soils).
- Specific control measures are needed to control water erosion and run-off to prevent excessive surface run-off from the site
- Limit impacts to the footprints to keep physical impacts as small as possible
- Areas for road and site lay-out should be minimized.
- Dust generation and vehicle associated pollution must be minimized.

13. METHODOLOGY USED FOR IMPACT RATING

The methodology includes the following:

- Descriptions of all methods, measures and instruments adopted during the undertaking of the applicable specialist study; and
- Impact rating method used, which is provided below.

13.1 NATURE OF IMPACT

The nature of the impact refers to whether an impact is positive or negative.

Table 18: Nature of impact

Status	Description	Rating
Positive	Benefit to the environment	+'ve'
Negative	Detriment to the environment	-'ve'

13.2 IMPACT TYPE

Each impact needs to be classified as a direct, indirect or cumulative impact. (Centre for Environmental Excellence, 2008) (Council on Environmental Quality, 2008).

Table 19: Impact type

Type	Description	Rating
Direct Impact	Is a reaction that is caused by the direct interaction of a planned action or activity on the receiving environment, e.g. the discharge of water into a water stream, the discharge of pollutions through a stack. Usually in close proximity to the action or activity.	Direct
Indirect Impact	Is a reasonably foreseeable reaction that is indirectly caused as a result of a planned action or activity, the effects/ impacts are usually later in time and farther removed from the action or activity, e.g. growth inducing effects, changes in patterns of land use, population density or growth rate and related effects on air, water, ground and ecosystems.	Indirect
Cumulative Impact	Is the impact on the environment, which results from the incremental impact of the action when added to other past, present and reasonably foreseeable future actions, regardless of undertakings by other industries, mines, developments or persons? Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time.	Cumulative

13.3 GROUPING OF IMPACT

The grouping of the impact refers to whether the impact will be a result of a planned project activities or unplanned project activities.

Table 19: Grouping of impact

Grouping	Description	Rating
Routine	Impact that occurs as a result of expected and planned project activities.	'R'
Non-Routine	Impact that occurs as a result of an unexpected and unplanned project activity. Usually occurs in emergency events.	'NR'

13.4 CERTAINTY (PROPABILITY) OF IMPACT

The certainty of the impact describes the likelihood of the impact occurring.

Table 20: Certainty of impact

Certainty	Description	Rating
Unlikely	Less than 40% sure that the impact or benefit will occur.	1
Possibility	Between 40% and 70% sure that the impact or benefit will occur.	2
Probable	Between 70% and 90% sure that the impact or benefit will occur.	3
Definite	Over 90% sure that the impact or benefit will occur.	4

13.5 SPATIAL EXTENT OF IMPACT

The extent of the impact refers to the spatial scale of the impact or benefit of the proposed project and the area over which it extends.

Table 21: Spatial extent of impact

Spatial Extent	Description	Rating
Site specific	Effects felt within the site boundary area.	1
Local	Effects are felt within 5 km radius from the site boundary area.	2
Regional	Effects are felt within a 50 km radius from the site boundary area.	3
National	Effects are felt beyond a 50 km radius from the site boundary area within South Africa.	4

13.6 DURATION OF IMPACT

The duration refers to the time scale of the impact or benefit in terms of the period of time that the surrounding environment will be affected or altered by the proposed project.

Table 22: Duration of impact

Duration	Description	Rating
Short term	Less than 5 years	1
Medium term	Between 5 and 20 years	2
Long term	Between 21 and 40 years	3
Permanent	Permanent impact	4

13.7 REVERSIBILITY OF IMPACT

Reversibility refers to the time it would take to reverse or undo the impact under discussion.

Table 23: Reversibility of impact

Reversibility	Description	Rating
Short term	Less than 5 years	1
Medium term	Between 5 and 20 years	2
Long term	Between 21 and 40 years	3
Permanent	Permanent impact, i.e. not reversible	4

13.8 SEVERITY (INTENSITY) OF IMPACT

The severity is the attempt to quantify the magnitude of the impact whether positive or negative, which is associated with the proposed project. The scale therefore accounts for the extent and magnitude but is subject to the value judgement.

Table 24: Severity of impact

Status of Impact	Severity	Description	Rating
Negative	Slight	• Minor deterioration; • Short to medium term duration; and • Mitigation is easy, cheap and quick.	1
	Moderately severe	• Moderate deterioration; • Medium to long term duration; and • Fairly easy to mitigate.	2
	Severe	• Marked deterioration; • Long term duration; • Serious and severe impact; and • Mitigation is very expensive, difficult or time consuming.	3
	Very severe	• Substantial deterioration; • Irreversible of permanent; and • Cannot be mitigated.	4
Positive	Slightly beneficial	• Minor improvement; and • Short to medium term duration.	1
	Moderately beneficial	• Moderate improvement; and • Medium to long term duration.	2
	Beneficial	• Large improvement; and • Long term duration.	3
	Very Beneficial	• Permanent improvement.	4

13.9 SIGNIFICANCE OF IMPACT

The significance of a positive or negative impact describes and evaluates the importance of that impact in accordance with the scope of the project. Impacts can be described and evaluated in terms of their type, extent, complexity, intensity and duration. This evaluation criterion provides a basis for comparison and the application of judgement (Department of Environmental Affairs and Tourism, 2002). The significance of an impact is calculated as follows:

(Severity + Reversibility + Duration + Spatial) x Certainty = Significance

Table 25: Significance of impact

Significance		Description	Rating
Very low(1)	Negative	• Constitutes as a short term effect, which is site specific; • Easily reversible by the application of easy, cheap or quick mitigation measures; • Mitigation might not even be required, and • Society and/or specialist view the change as negligible.	0-4
	Positive	• Slightly beneficial impact, which constitutes a minor improvement; • Short term duration; and • Enhancement measures to be implemented to increase the effect of the positive impact.	
Low (1 - 2)	Negative	• Marked deterioration; • Short to medium term; • Effects are not substantial. • Society and/or specialists view the change as unimportant; and • Mitigation is easy, cheap or quick.	5 - 15
	Positive	• Marked improvement; • Short to medium term; and • Enhancement measures to be implemented to increase the effect of the positive impact.	
Moderate (2 - 3)	Negative	• Constitutes as medium to long term effect; • Effects are real but not substantial and ; • Society and/or specialist do not view the impact as substantial and very important; and • Mitigation is fairly easily possible.	16 - 35
	Positive	• Marked improvement; • Medium to long term; • Effects are real, but not substantial; and • Enhancement measures to be implemented to increase the effect of the positive impact.	
High (3-4)	Negative	• Long term effect; • Society and specialist view the change as very serious; • The reversibility of the impact is long term; and • Mitigation is very expensive, difficult and time consuming.	36-63
	Positive	• Long term effect; • Society and specialist view the change as very positive; and • Enhancement measures to be implemented to increase the effects of the positive impact.	
Very high (4)	Negative	• Constitutes as a permanent change to the environment; • Society and/or specialist view the change as very serious; • The impact cannot be reversed; and • The impact cannot be mitigated.	64
	Positive	• Constitutes as a permanent change to the environment; • Society and specialist view the change as very positive; and • Impacts cannot be reversed.	

14. IMPACT ASSESSMENT

Table 26: Predicted impact assessment of the proposed mining activity on the soils

Project phase	Nature	Certainty	Extent	Duration	Reversibility	Severity	Significance
Before Mitigation							
Construction	-	4	2	1	3	3	**36**
Operation	-	4	2	4	3	3	**48**
Decommissioning	-	2	2	2	3	3	**20**
After Mitigation							
Construction	-	4	1	1	3	2	**28**
Operation	-	4	2	4	3	3	**36**
Decommissioning	-	2	2	2	3	3	**20**

15. DUST GENERATION AND VEHICLE IMPACT ASSESSMENT

15.1 DUST GENERATION

During the operational time all vegetation will be removed and creates a potential for wind erosion and therefore dust generation.

- A soil with low clay contents is susceptible to wind erosion, but has a low dust generation potential.
- Soils with high clay contents have an inherent stability and have a low dust generation potential, except for Vehicle movement. Vehicles can cause powdering and breaking of the soil structure. It is recommended that all roads should be gravelled.
- Soils with clay contents between 5 and 25 percent have a high dust potential. Clay contents of the area are illustrated in Figure 12, and area susceptible to a high dust generation potential is illustrated in red.

Three potential areas of dust formation are identified:

- Open-pit areas: Dust control can be achieved by additives like molasses or watering on a regular base.
- Stockpiling areas: Rock armouring of the stock piles can reduce wind and water erosion.
- All roads: Use of gravelled roads.

15.2 ON SITE VEHICLE OPERATIONS

- Vehicle movement should be minimized and restricted to the construction site on gravelled roads, in order to reduce potential rill erosion and dust formation.
- Maintain vehicles and prevent and address spillages of lubricants and petroleum.

16. CONCLUSIONS OF IMPACT ASSESSMENT

- As mentioned previously, generally the soils are severely degraded through erosion and top soil loss. The majority of area has a poor basal cover, and it is prone to compaction and crust formation
- A large percentage of the area has very shallow and rocky soils as well as surface rock outcrops.
- The soils are not high potential arable soils and have low soil fertility. This has the implication that rehabilitation will be complex and special measures need to be implemented to prevent soil loss through wind and water erosion (see Appendix 1).
- Water for irrigation purposes is in some areas of poor quality. Special measures should be put in place to protect surface and sub-surface water sources from further contamination.

17. RECOMMENDATIONS

17.1 MITIGATION MEASURES REQUIRED

17.1.1 SOIL STRIPPING IN CONSTRUCTION PHASE

- The Red and Yellow Apedal soil groups are suitable as growing medium; effort should therefore be made to strip the topsoil separate from the underlying material (see Appendix) for later use.
- Soils in the wetland should be kept undisturbed.
- Average soil depths range from 40-150cm and are on average110cm deep. If soil stripping is necessary, it is recommended to strip only 40-60cm of the

soil. These estimates take into consideration a possible 10% topsoil loss through compaction and allow the rehabilitated areas to be returned to the pre-mining land capability, i.e. arable cropping and grazing land.

- Any soil that might possibly be contaminated during the construction phase should be stripped and stockpiled in advance of construction activities.
- The stripped soils should be stockpiled upslope of areas of disturbance to prevent contamination of stockpiled soils by runoff or seepage.
- All stockpiles should also be protected by a bund wall to prevent erosion of stockpiled material and deflect water runoff.
- Stockpiles should be placed where possibly on the areas covered by stony or rocky soils (Mispah, Glenrosa and Coega).
- Care should be taken that stockpiles do not to block too many drainage lines as high intensity rainfall events can occur in this area (e.g. the rainfall in January 2013 exceeds the average annual rainfall).

17.1.2 OPERATIONAL PHASE

- Stockpiles can be used as a barrier to screen operational activities. If stockpiles are used as screens, the same preventative measures described above should be implemented to prevent loss or contamination of soil.
- The stockpiles should not exceed a maximum height of 6m and it is recommended that the side slopes and surface areas be vegetated in order to prevent water and wind erosion and to keep the soils biologically active.
- If used to screen operations, the surface of the stockpile should not be used as roadway as this will result in excessive soil compaction.

17.1.3 DECOMMISIONING AND REHABILITATION

Detailed recommendations concerning a sustainable approach to soil rehabilitation of opencast mining areas are given in the appendix. The following issues need to be taken into consideration before, during mining operations, with closure and rehabilitation:

- Loss of topsoil and usable soil

    - Strip all usable soil and stockpile.
    - Vegetate long-term soil stockpiles
- Contamination of topsoil and stockpiled soil
    - Prevent contamination of topsoil and stockpiled soil.
    - Site all soil stockpiles upslope from any mining / development activities
    - Position stockpiles upslope of mining areas, or as screens to restrict visibility of the mining operation provided that in doing so, the stockpile is not exposed to the risk of seepage or dirty water contamination.
- Erosion of stockpiled soil
    - Ensure that all stockpiles have a storm water diversion berm for protection against erosion and contamination by dirty water.
- Loss of soil biodiversity
    - Most soil stockpiles become sterile as soil microbiology dies off due to long-fallow syndrome. Compost, Kraal Manure and / or humic and microbial substances can be used to restore soil biology.
- Probability of compaction
    - The footprints of stockpiles on deep soils (not necessary for shallow soils) must be loosened after removal of the stockpiles, because of compaction during the stockpiling process.

17.1.4 MONITORING AND MEASUREMENT REQUIREMENTS

- Sampling sites need to be established down- stream on neighbouring farms.
- Regular water quality monitoring also need to take place in the Sand River to monitor any impact the proposed development might have on the regional surroundings.

18. MANAGEMENT RECOMMENDATIONS

The area can be converted to mining, but measures must be put in place to limit soil erosion and contamination of boreholes and surface water and the wetlands.

19. BIBLIOGRAPHY

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20. APPENDIX 1*:* REHABILITATION OF OPENCAST MINING SOILS

1. INTRODUCTION

Global agriculture is facing a trend in yield decline for most crops. This is specifically applicable to crops that are practised under a mono-cropping system. It is a well-known scientific fact that monoculture has a negative impact on soil fertility and potential.

With mono-cropping and overuse of land, it has become necessary for farmers to resort to more drastic measures to maintain yields. One such practise is to increase N, P and K chemical fertilisers at ever increasing costs, because the perception is that the higher the fertiliser levels the higher the yield.

This same mind-set is prevalent with the rehabilitation of opencast mining areas. The impact of mining operations is just so much amplified as the whole soil profile with all the integrated soil physical, chemical and biological processes is destroyed. This is often the result of a lack of understanding that soil is a living eco-system and that there is a difference between soil fertility and plant nutrition. There is also a difference in understanding the term topsoil from a soil science and mining perspective.

A distinction must be made between restoring soils to previous inherent potential for crop production and sustainable rehabilitation. As previously mentioned soils form over a long period of time with various processes involved. The opencast mining operations totally disturb these process and soil forming factors.

It is not possible to restore the soil potential and initial characteristics to its original state but huge improvements can be made in the methodology of stripping and re-dressing of soil material to ensure sustainability of rehabilitation. Over time these soils can produce proper vegetation and grazing of cattle and arable crop production at lower yields then the initial soil potential.

To achieve this it is necessary to understand the soil forming factors and processes and the difference between soil fertility and plant nutrition.

2. DEFINITION OF SOIL

Soil is an open living ecosystem and can therefore be defined as a function of physical, chemical and biological processes.

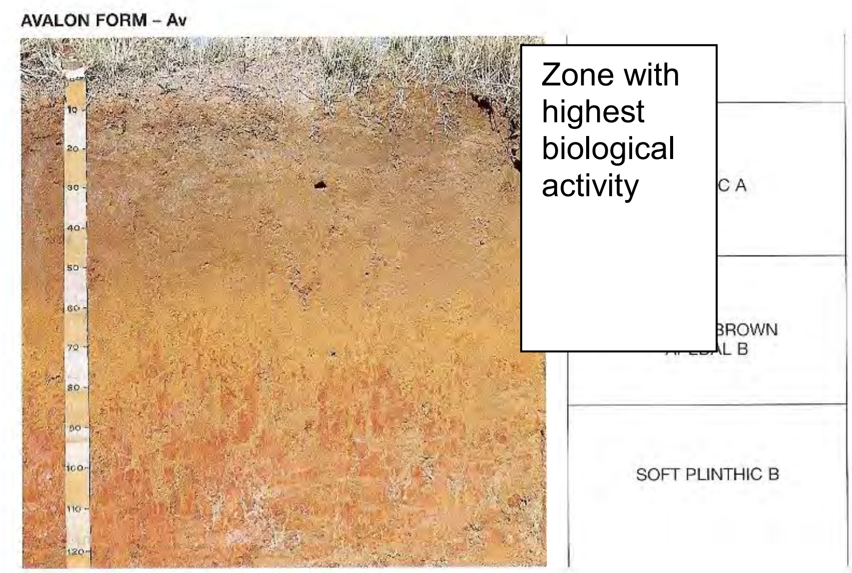
3. SOIL FORMING PROCESSES

The following factors are involved in soil formation:

- Parent Material (geology, e.g. sedimentary rock (sandstone), acid igneous (granite) or basic rock dolerite) etc.)
- Topography (slope of landscape)
- Climate (wind, water, temperature etc.)
- Microbial Activity and microbial diversity
- Time (soil formation occurs over a long time period, e.g. 1cm of topsoil is formed over 100yrs)

These factors with different physical, chemical and biological processes combine under specific conditions to form specific soil diagnostic horizons with a unique character and inherent soil fertility.

Photo 1: Avalon soil showing different horizons (Soil classification working group, (1991)



4. FERTILITY / PLANT NUTRITION

Fertility refers to the inherent capacity of a soil to supply nutrients to plants in adequate amounts and in suitable proportions as well as oxygen and moisture to maintain a healthy soil bio-diversity (active micro-biology, immune system). The focus here is soil health.

Plant nutrition refers to the soils ability to supply nutrients to the plant so it can complete its reproductive cycle. The nutrient status of the soil can be manipulated by adding organic and inorganic fertilisers according to the crop's need. The focus here is on the crop's needs.

It can now be summarised that different soils have different levels of soil fertility according to the combination of the soil forming factors and soil processes involved under specific conditions. All these factors and processes are interlinked and no single soil type has all these factors in the ideal combination, therefore the yield potential and use of soils varies.

Unfortunately soil fertility and nutrition was relegated to a simple recipe of four elements provided through chemical fertilisers e.g. Nitrogen (N), Phosphorous (P), Potassium (K) and Zinc (Zn) to meet only the crop needs at the expense of soil fertility. Very little attention was given to the important role of bio-diversity and active microbiology in plant nutrition. It is only in the last couple of years that there is a serious interest on this matter.

5. THE ROLE OF BIODIVERSITY

Active and healthy soil microbiology is able to:

- Mineralise nitrogen, phosphorous and sulphur
- Suppress nematodes, bacterial and fungal diseases
- Actively decompose organic material
- Improve root development with the result of better nutrient and water uptake
- Recycle and keep nutrients available for plants, especially micro-nutrients
- Improve soil physical and chemical conditions by increasing the humus content
- Improve water holding capacity of soil
- Less KWa power needed for soil tillage

6. MINING PRACTISES THAT CONTRIBUTE TO THE DESTRUCTION OF SOIL FERTILITY AND LOSS OF BIO-DIVERSITY

- Incorrect stripping of topsoil. Various soil horizons with different properties are stripped together and stockpiled.
- Stockpiling of proper topsoil with sterile or acidic subsoil (plinthic or grey clay
- material)
- Long periods of stockpiling creates anaerobic conditions, resulting in a decline in microbial activity and/ or changes in bio diversity.

- Soils are nutritionally stripped and have low microbial activity
- Long fallow periods are as detrimental to soil health as no fallowing.
- Incorrect soil placement with rehabilitation (plinthic and grey clay material on the soil surface), causes slaking, increasing crust formation, and compaction resulting in poor infiltration, aeration and increased run-off and erosion. These plinthic and grey clay materials are also basically sterile in terms of microbial activity
- Poor irrigation practises. Over irrigation causes leaching of nutrients.
- Decline in water quality in major river systems is causing a gradual build-up of salinity and sodicity.

In most cases poor seed germination or die-back of seeded grass occur because of a combination of these factors mentioned.

The following can be done to improve soil bio-diversity and therefore sustainable rehabilitation:

- Crop rotation
- Fallowing and green-manuring
- If there is not sufficient time to introduce proper fallowing or green-manuring practises compost can be applied to the soil

7. RECOMMENDATIONS FOR PROPER REHABILITATION OF SOILS DISTURBED BY OPENCAST MINING OPERATIONS

7.1. STRIPPING

- Sequential stripping of soil horizons. In some cases the A and A-Horizons can be stripped together. This has a huge practical, logistics and cost implication, but until such time that it is implemented, no improvement in sustainability of rehabilitation will occur
- Smaller stockpiles and seeding of stockpiles with grass

7.2. LANDSCAPING AND REPLACEMENT OF SOILS

- It is imperative to reshape the landscape as close as possible to its original topographic features (e.g. slope and drainage lines, wetlands). Various surveying and GIS software can be used to achieve this goal
- Where possible use the "freshest" stripped soils for redressing, as this will alleviate the soils becoming sterile or lose microbial activity
- Place the plinthic and grey clay material in the sub-soils and the original A and A-Horizon material on top. Create an environment where the topsoil is at least 40-60cm deep for proper aeration, water-holding capacity and drainage, resulting in proper root development

7.3. SEEDING WITH GRASS SPECIES AND LEGUME CROPS

- A three stage approach can be implemented where pioneer species are planted to create a soil environment for sub-climax species. After some time climax species can be introduced. There are many case studies where reseeding is necessary because the sub-climax and climax grass species die back after the first or second season
- Legume crops like soya, cow peas, Dolichos, or Lucerne can be introduced to improve the soils microbial activity and soil structure.
- Compost and other organic humic substances can be used to speed up the process of restoring soil biodiversity

8. THE ROLE OF COMPOST AND OTHER HUMIC SUBSTANCES IN RESTORING BIODIVERSITY IN DISTURBED SOILS

Many books have been written about the role of compost in improving soil bio-diversity as well as the making of compost. It never became a standard practise in commercial agriculture for the following reasons:

- It is bulky and transport costs did not make it viable

- Practical problems with application
- The value was always measured in terms of N, P and K content and in monetary terms.

Times have changed however and recent research across the world has shown that soil bio-diversity has great value in commercial agriculture and rehabilitation both from fertility as well as a plant nutrition perspective. Compost is a great and fairly quick way in restoring soil fertility although it must be made clear that it is a long term approach that is necessary. Organic and humic products can overcome to some degree the practical and logistical problems posed of importing large volumes of organic matter.

9. SUMMARY

- There is no quick fix solution to the seriously negative impact of opencast mining on high potential soils
- Proper stripping and replacement of soils is imperative for any proper redressing and seeding with grass species to take place
- A holistic long term, staged approach is necessary to restore physical, chemical and biological processes in the growth medium
- Long term monitoring and relevant adjustments must be made to restore the soils to some sort of arable crop production potential to ensure future food security problems that might loom.

21. APPENDIX 2: CURRICULUM VITAES

CURRICULUM VITAE OF S. NKOPANE

21.1.1 PERSONAL DETAILS

- **Name :** Nkopane S.L
- **Date of Birth :** 11th January 1972
- **ID Number :** 720111 5172 089
- **Marital Status :** Married
- **Cell:** (082) 828 – 3412
- **Email address:** setenane@gudaniconsulting.co.za

21.1.2 FORMAL QUALIFICATIONS

- BSc – Physical Geography and Biology: University of Lesotho, 1994
- BSc (Hon) – Environmental Sciences: University of Cape Town, 1995
- MSc – Environmental Impact Assessment: University of Cape Town, 1997

21.1.3 PROFESSIONAL AFFILIATIONS

- SACNASP – 400022/13
- International Association of Impact Assessments – South Africa (IAIA-SA).
- IAIA-SA – Limpopo Regional Chairperson 2012/13.

21.1.4 EMPLOYMENT HISTORY

- March 1997 – November 1997, Environment Officer, Department of Environmental Affairs, Gauteng Province.
- November 1997 – February 2006. Deputy Director: Mine Rehabilitation, Department of Minerals and Energy, Limpopo Province
- April 2006 – February 2008, Regional Environmental Manager – Venetia Mine and The Oaks Mine – both DBCM mines.

- March 2008-Current , Managing Director, Gudani Consulting

21.1.5 WORK EXPERIENCE AND PROJECTS

- EMP Amendment – Modikwa Platinum Mine – 2009
- Prospecting Right Application (including EMP) – Fine Asset Investments – 2009
- IWULA – Bus Rapid Transit (BRT) Project – Mabopane to Pretoria – 2009
- EMP for proposed Sefateng Chrome Mine – Corridor Mining Resources – 2010
- Environmental Impact Assessment – Bulk Water Supply Pipeline – Lephalale Local Municipality – 2010
- Environmental Impact Assessment – Giyani Bulk Water Supply Pipeline – Department of Water Affairs - 2010
- Environmental Impact Assessment – Upgrading of R35 Main Road – Amersfoort to Morgenzon – SANRAL – 2010
- Waste Rock Dump Plan and Rehabilitation Strategy – Modikwa Mine – 2010/11
- Stakeholder Empowerment & Capacity Building – Mogalakwena sub-Catchment, Limpopo – Department of Water Affairs – 2010/11.
- EMP Performance Assessment and Closure Costing – Modikwa Mine - 2011
- ISO 18001/14001 Internal Audit – Thabazimbi Iron Ore Mine – 2011.
- Strategic Environmental Assessment – Agricultural Development – Lephalale Municipality – 2011.
- Institutional Assessment and Re-Engineering of NCWSTI into University of Limpopo – The Mvula Trust – 2011
- Feasibility Study on Small Scale Mining Potential within Sekhukhune District Municipality – Sekhukhune Development Agency – 2011
- EMP Amendment and Closure Costing– Silicon Smelters, Polokwane – 2011
- Stakeholder Engagement – Limpopo Catchment Area – Department of Water Affairs – 2012

- Atmospheric Emissions License – Silicon Smelters – 2012
- Environmental Impact Assessment – Bulk Water Supply and Sewage Pipeline – Lephalale Local Municipality/COGHTA – 2012
- Environmental Impact Assessment for Commercial Site Development - Ratsoma Properties, 2012
- Public Participation Process – Harriet's Wish Mining Project – Hacra Mining and Exploration (Pty) Ltd – 2012
- Environmental Screening Process – Relocation Project De Hoop Dam: ORWRDP – Phase 2 – Department of Water Affairs, 2012
- Public Participation Process – Jaglust and Lwala Mining Projects – Samancor Eastern Chrome Mine – 2012/13
- EMP Amendment – Doornbosch Triangle Project - Modikwa Platinum Mine – 2012/13

CURRICULUM VITAE OF F. BOTHA

21.2.1 PERSONAL DETAILS

- **Name :** Botha, F
- **Date of Birth :** 9 June 1959
- **ID Number :** 59 06095074087
- **Marital Status :** Married
- **Cell:** 0849005933
- **Email address:** fbecosoil@gmail.com

21.2.2 FORMAL QUALIFICATIONS

- B.Sc (Pedology) from PU for CHE, 1984
- B.Sc (Hon) Pedology) from PU for CHE, 1988
- B. Comm. (Economics and Business Economics) from UNISA, 2001.

21.2.3 PROFFESIONAL AFFILIATIONS

- Soil Science Society of South Africa
- South African Soil Surveyors association
- Land Rehabilitation Association of SA (formation in process)
- SA Irrigation Institute

21.2.4 EMPLOYMENT HISTORY

- 1984-1988, Trans-Agric, College of Agriculture, Senior Lecturer in Soil Science.
- 1988-1991, ICI-Kynoch Agrochemicals, Training Co-coordinator
- 1991-1996, Lowveld College of Agriculture, Senior Lecturer in Soil Science.
- 1997-2004, SA Sugar Association, Senior Extension Officer, Malelane region.

- 2004-2007, Advanced Nutrients SA, Technical Director.
- 2007-Present, Private Consultancy and Director of Eco Soil.

21.2.5 WORK EXPERIENCE AND PROJECTS

- 8 years' experience as an extension officer, with the focus on sugarcane production under irrigation in the Malelane region.
- Initiated and Assisted SASRI research Dept with various trials related to sugarcane production.
- Involvement in pedological and geological surveys for Forestek (35 000ha's), ARC and private individuals for forestry, game ranching, farming enterprises and new agricultural developments (150 000ha).
- Functioned as project leader on a number of large scale soil survey projects, e.g. Donkerhoek Agricultural project, Mpmalanga
- Pedological specialist studies for environmental impact assessments (EIA's) as well as a number of economic and agronomic feasibility studies for new agricultural developments.
- 13 Years lecturing experience in soil science at agricultural colleges.
- Consultation on biological and soil health principles on various agricultural projects
- At present consulting on the following Precision farming sampling and mapping in the maize sugar and industry
    - Feasibility studies on new sugarcane and agricultural projects under irrigation in Southern Africa
    - Environmental Impact Assessments for mining and new projects
    - Rehabilitation of opencast mining soils

CURRICULUM VITAE OF A. HATTINGH

21.3.1 PERSONAL DETAILS

- **Name :** Hattingh, A. M.
- **Date of Birth :** 9 December 1956
- **ID Number :** 5612090077089
- **Marital Status :** Married
- **Cell:** 0828536228
- **Email address:** astridhattingh@yahoo.com

21.3.2 FORMAL QUALIFICATIONS

- BSc Pedology, PU for CHE, 1977
- BSc (Hon) Pedology, PU for CHE, 1978
- MSc Pedology, PU for CHE, 1983

21.3.3 MEMBERSHIP

- Soil Science Society of South Africa.
- International Soil Science Society.

21.3.4 EMPLOYMENT HISTORY

- 1979 –1993 Dept. of Agriculture (Highveld Region) as Researcher.
- 1993-1996 Assistant Director Soil Science.
- 1997-1998 Part time lecturer at PU for CHE in clay mineralogy, soil physics, irrigation, drainage, soil chemistry.
- 1997 Part time at REHAB. Soil consultant
- 1998-2002 Own business: Handrid Flora: Seedlings and vegetable production.
- 2002- 2003 Own Business in participation with Africa Plus Projects and Geoquip. Irrigation scheduling and soil consultant.

- 2004 Consultant Techniland. Precision farming.
- 2006 GCI- ARC. Researcher
- 2007 –2008 Africa Geo Environmental Services (AGES) GIS specialist, Soil Scientist
- 2009-2010 Part time Lecturer at Potchefstroom University and Agricultural College Potchefstroom. Private consultation.
- 2011-present. Precision Farming Own Business. Africa and mine Projects with GIS interpretation of soil and land capability studies.

21.3.5 WORK EXPERIENCE AND PROJECTS

- Reports and GIS work for Africa (Tanzania, Mozambique) Projects: Basanza/Lugufu, Kigoma, Kilombero, Kasulu, Mopeia, Rufiji.
- Management Plan for Vredefort World Heritage Site: GIS and agriculture
- Geotechnical reports and GIS work.
- Planning and research of various projects
    - Research: Water holding capacity – Influence of clay content and mineralogy
    - Determination of field capacity and wilting point.
    - Water conservation practices
    - Stubble mulching
    - Evaluation of cultivation practices
    - Recompaction rate of soils with different clay contents.
    - Cone penetrometer studies.
    - Water consumption of maize at different plant densities.
    - Calibration of neutron water meters and gamma density meters.
    - “Basin cultivation”
    - Handling of research plots: plant, herbicides and pesticides, cultivation, harvesting, soil water and compaction monitoring etc.
    - Nitrogen transfer
    - Organic growing of vegetables

  - Fertilisation of vegetables
  - Water conservation and irrigation for small-scale vegetable farming.
  - Soil acidity
  - Fertilisation of pasture
  - Phosphorus studies.
- Head of soil analysis laboratory:
  - Soil, plant, water, lime, in vitro analysis --- supervisor
  - Interpretation and approval of results
  - Fertiliser recommendations- grain, pasture and vegetables.

21.3.6 POSITIONS HELD AND COMMITTEE PARTICIPATION

- Assistant Director Soil Science. Dept. Of Agriculture Northwest Province (Administration, supervision of junior researchers, technicians and head of laboratory).
- WRC steering committee projects.
- 1994 Secretary of SSSSA Congress organising committee.
- Member of research steering committee Highveld Region.
- Soil interest group of Western Transvaal: Founder member and Secretary and Chairlady-several times.
- Combined Soil, Crop Science, Crop protection Congress: Organizing committee 1996 and 2012
- Organizing convenor: Precision Farming Congress for 2013

CURRICULUM VITAE OF J. HATTINGH

21.4.1 PERSONAL DETAILS

- **Name :** Hattingh, J. M.
- **Date of Birth :** 17 October 1950
- **ID Number :** 501017 5010 085
- **Marital Status :** Married
- **Cell:** 0798936537
- **Email address:** soilhats@safricom.co.za

21.4.2 FORMAL QUALIFICATIONS

- BSc (Pedology) University: PU for CHE
- BSc (Hon) (Pedology) University: PU for CHE
- MSc (Engineering Geology) University: Purdue (Indiana USA)

21.4.3 PROFESSIONAL AFFILIATION

- International Society for Terrain Vehicle Interaction
- Soil Science Society of South Africa

21.4.4 EMPLOYMENT HISTORY

- 1982 - 1998: Lecturer in Soil Science at the PU for CHE.
- 1998 - 2003: Own business (Handrid Flora) and technical consultant for Envirogreen (Pty) Ltd.
- 2003 - 2005: Research and development in precision farming for Techniland (Pty) Ltd
- 2005 - 2007: Specialist agronomist in precision agriculture for Cal Tech (Pty) Ltd

- 2007-present: Own business in precision agriculture & consultant OmniPreciseTM

21.4.5 WORK EXPERIENCE AND PROJECTS

- Planning and implementing research projects
    - Trafficability of vehicles (53 Reports)
    - Terrain evaluation
    - Dispersion of soils
    - Phosphate adsorption.
    - Soil Compaction (Forestry)
    - Cone penetrometer and Bevameter
    - Backfill material
    - Erosion
    - Rehabilitation of Gold tailings dams
- Lecturing at PU for CHE
    - Soil Chemistry (4 years)
    - Clay mineralogy (5 years)
    - Soil Mechanics (17 years)
    - Soil Physics (6 years)
    - Irrigation (6 years)
    - Drainage (6 years)
    - Erosion (6 years)
    - Soil classification (7 years)
    - Land use planning and sustainability (5 years)
- Post graduate leader
    - Leader of five M.Sc dissertations
    - Examiner of various M.Sc dissertations.
- Research projects
    - Reconnaissance soil investigations (soil mapping) (Venda and Gazankulu)

- Soil investigation for irrigation purposes (Taung and Klein Letaba)
- Soil investigation for township development (Potchefstroom, Klerksdorp, Krugersdorp, Fochville and Nylstroom)
- Soil investigation for precision farming (more than 40 000ha) (Schweizer Reneke, Hoopstad, Hertzogville, Klerksdorp, Viljoenskroon, Bothaville, Lichtenburg)
- Rehabilitation of slimes dams (FS N 6, ST Helena and Beatrix slimes dams)

21.4.6 POSITIONS HELD AND COMMITTEE PARTICIPATION

- Acting head of Department of Soil Science. PU for CHE
- Administration, management, training, research and projects
- Acting director of Institute for Soil Science Research. PU for CHE
- Member of the Faculty Board: Natural Science. PU for CHE
- Executive member of the Environmental Earth Science Group (4 years)
- Member of various ARMSCOR panels
- Member of various WRC panels

CURRICULUM VITAE OF JL PAUER

21.5.1 PERSONAL DETAILS

- **Name :** Pauer, J.L.
- **Date of Birth :** 13 June 1957
- **ID Number :** 5706135034087
- **Marital Status :** Married
- **Cell:** 0724676449
- **Email address:** jlpauer@vodamail.co.za

21.5.2 FORMAL QUALIFICATIONS

- BSc Pedology PU for CHE, 1981
- BSc Hon Pedology, PU for CHE, 1990

21.5.3 ROFFESIONAL AFFILIATIONS

- Soil Science Society of South Africa.
- SA Mapping Society

21.5.4 EMPLOYMENT HISTORY

- 1982-1995 Institute for Pedological Research, PU for CHE.
- 1995-1998 Private consultancies in Soil Surveys for Mondi forests.
- 1999-2003 Private consultancies to commercial farmers.
- 2003-2004 Part time consultancies to Techniland a division of Afgri.
- 2005-2012 Partnership with Pedo –Kode, Soil surveys in Mpumalanga and Gauteng
- 2012 – Present Soil Surveys for Correck BDY in Tanzania and Mozambique for rice and sugar projects.

CURRICULUM VITAE OF MJ BOTHA

21.6.1 PERSONAL DETAILS

- **Name :** Botha, M. J
- **Date of Birth :** 22 May 1957
- **ID Number :** 5705225161081
- **Marital Status :** Married

21.6.2 FORMAL QUALIFICATIONS

- National Diploma in Soil Science at Pretoria Technicon,1978
- 2 Year Military training (1979-1981) spec. Photogrammetry and Cartography

21.6.3 EMPLOYMENT HISTORY

- June 1977 - Sept. 1995 : Institute for Soil , Climate and Water (ARC - Agriculture Research Council)
- Oct. 1995 - Feb. 1999 : Subcontractor to BLP Soil Surveys
- April 2002 - August 2003 : Subcontractor to AfriGIS Environmental Solutions
- Aug 2003 - May 2005 : Soil Consultant to Afgri (Technilands) – Pretoria
- Jun 2006 – Jun 2007 : Soil Consultant to Unie-Tech and McCains
- Jul 2007 – present, private soils consultant for various projects.

21.6.4 WORK EXPERIENCE

- Soil Surveyor (June 1977 - September 1995). 20 Detail Soil surveys (1:5000 - 1:10000 scale) - 169 349ha
- Detail SOIL SURVEYS (SIRI. Report No. GB/A/86/27) 1:5 500 2333ha
- Detail soil surveys (SIRI. Report No. GB/A/86/28) 1:5 000 en 1:6 000 > 10 000ha

- Black farmers development: Detail soil survey of Doornkop 239IQ and Kaalfontein 529IQ, Westonaria 1:10000, 75mgrid (ISCW Report No. GW/A/94/80)
- Detail soil survey Kakamas area, 1:10000, 11 652ha, (ISCW Report No. GB/A/87/26)
- Detail soil survey Rietrivier area (ISCW Report Nr. GB/A/88/4)
- Semi detail soil surveys (1:25000 scale) - 393 900ha
- 2 Recon and Landtype surveys (1:50000 scale) - 3 120 625ha
- Madikwe – game reserve. Soil survey 1: 50 000, 70 000ha, ISCW (Report No. GW/A/94/58)
- Reconnaissance surveys on soils adjacent to the Palala-river north of the Waterberg, 42 000ha (ISCW Report No. GB/A/87/28)

CURRICULUM VITAE OF JHA THIART

21.7.1 PERSONAL DETAILS

- **Name :** Thiart, Johannes Hendrik Albertus
- **Date of Birth :** 22 May 1957
- **ID Number :** 4910105045088
- **Marital Status :** Married
- **Cell:** 0823758909
- **Email:** johan@hispeople.co.za

21.7.2 FORMAL QUALIFICATIONS

- National Diploma (Agric), Technical College Pretoria
- Agricultural Resource Identification and Planning (Passed with distinction)

21.7.3 EMPLOYMENT HISTORY

- January 1969 – October 1999 (29 years), Employed by Department of Agriculture, Highveld region, Agricultural and Resource Conservation Technician.
- 1999-2001, Private consultancy, Soil classification and resource Planning
- 2001-2008, Senwes Co-op, Precision Farming division, soil surveys and resource planning
- 2008-Present, Subcontract to Eco Soil, Soil classification and land-use planning for EIA's and feasibility studies for new agricultural projects.

21.7.4 WORK EXPERIENCE

- Experience in Soil Classification on various projects for Dept of Agriculture in the Free State and the previously known Highveld region

- Lectured and assisted in the presentation of the National Resource and Classification Course presented in Potchefstroom
- Lectured for 10 years at the Trans-Agric College of Agriculture, Agronomy and Farm Planning.
- Have experience in Commercial and Emerging farmer extension services.
- Have 8 years' experience in precision farming classification and Mapping.