Environmental Consolidation and Amendment of the Environmental Management Programme for Thubelisha, Trichardtsfontein and Vaalkop Operations

Soil, Land Capability and Land Use Assessment Report

Project Number:

SAS3869

Prepared for:

Sasol Mining (Pty) Ltd

December 2017

Digby Wells and Associates (South Africa) (Pty) Ltd
Co. Reg. No. 2010/008577/07. Turnberry Office Park, 48 Grosvenor Road, Bryanston, 2191. Private Bag X10046, Randburg, 2125, South Africa
Tel: +27 11 789 9495, Fax: +27 11 069 6801, info@digbywells.com, www.digbywells.com

This document has been prepared by Digby Wells Environmental.

Report Type:	**Soil, Land Capability and Land Use Assessment Report**
Project Name:	**Environmental Consolidation and Amendment of the Environmental Management Programme for Thubelisha, Trichardtsfontein and Vaalkop Operations**
Project Code:	**SAS3869**

Name	Responsibility	Signature	Date
Siphamandla Madikizela (Manager: Rehabilitation and Soil)	Report writer		July 2017 January 2018
Brett Coutts (Divisional Manager: Ecology and Atmospheric Sciences)	Report reviewer		August 2017
Renée van Aardt (Principal Closure Consultant)	Exco reviewer		August 2017

DECLARATION OF INDEPENDENCE

Digby Wells and Associates (South Africa) (Pty) Ltd

Contact person: Siphamandla Madikizela

Digby Wells House
Turnberry Office Park
48 Grosvenor Road
Bryanston
2191

Tel: 011 789 9495
Fax: 011 789 9498
E-mail: siphamandla.madikizela@digbywells.com

I, Siphamandla Madikizela as duly authorised representative of Digby Wells and Associates (South Africa) (Pty) Ltd., hereby confirm my independence (as well as that of Digby Wells and Associates (South Africa) (Pty) Ltd.) and declare that neither I nor Digby Wells and Associates (South Africa) (Pty) Ltd. have any interest, be it business, financial, personal or other, in any proposed activity, application or appeal in respect of Sasol Mining (Pty) Ltd, other than fair remuneration for work performed, specifically in connection with the proposed Environmental Management Programme Consolidation.

Full name:	Siphamandla Madikizela
Title/ Position:	Soil Scientist
Qualification(s):	MSc in Soil Science
Experience (years):	4
Registration(s):	SACNASP (*Prof. Nat. Sci:400154/17*)

EXECUTIVE SUMMARY

Introduction

Digby Wells Environmental (hereafter Digby Wells) was appointed by Sasol Mining (Pty) Ltd to conduct a soils, land capability and land use assessment on the Vaalkop area, in Delmas, Mpumalanga Province of South Africa and consolidate Environmental Management Programme for all areas (Vaalkop and Thubelisha). To identify soils accurately, it is necessary to undertake a soil survey. The aim is to provide an accurate record of the soil resources of an area. Land capability, land use and agricultural potential are then determined from these results. The relevant project components include the following:

- Reviewing of all the existing information done by Earth Science Solutions;
- The description of soil forms found in the project area;
- Determining the existing land capability;
- Determining the current land use;
- Soil chemical and physical properties; and
- Impact assessment associated mining on soils.

Project Description

The Thubelisha Project which includes the Trichardtsfontein Mine, Vaalkop and Twistdraai Colliery: Thubelisha Shaft is located between the town of Trichardt and Bethal in the province of Mpumalanga. The town of Evander is 17 km to the West and Secunda is 10km South West of the Trichardtsfontein and TCTS mining area. Vaalkop is located 5 km southeast of Bethal and 17 km southwest of Trichardt. The Thubelisha Project area and coal reserve are located within the Highveld East Magisterial District, the Gert Sibande District Municipality and the Govan Mbeki Local Municipality.

Methodology

As part of the desktop assessment, baseline soil information was obtained from South African land type data published with maps at a scale of 1:250 000 by the Institute for Soil, Climate and Water (ISCW) of the Agricultural Research Council (ARC). A review of all the existing soils information conducted by Earth Science Solutions for Thubelisha was carried out.

A detailed study of the soils within the Vaalkop area was conducted during field visits in February and June 2017. A free survey method was used where it starts with a detailed physiographic aerial imagery interpretation and the surveyor actually walks most of the landscape, usually in traverses "across the grain", concentrating on the proposed infrastructure areas. The surveyor chooses sample points in order to systematically confirm a mental model of the soil-landscape relationships, draw boundaries and determine map unit composition. Soils were investigated by augering to a maximum depth 1.2 m or to the depth of refusal. Soil survey positions were recorded as waypoints using a handheld GPS. At each observation point, the South African Taxonomic Soil Classification System was used to describe and classify the soils. Land capability was determined by assessing a combination of soil, terrain and climate features using the approach adopted by Chamber of Mines of South Africa Guidelines for the Rehabilitation on Mined Land (2007). Land capability is defined by the most intensive long term sustainable use of land under rain-fed conditions. Land use was determined by aerial imagery, ground-truthed during the site visit.

Findings

The land type data indicated that the dominant land types were Bb4 and Ea20. The dominant soils are Hutton (Red), Avalon (Yellow-brown), Mispah, Rensburg, Arcadia, Swartland, Katspruit, Glencoe, Kroonstad, Longlands and Westleigh. The land capability consists of predominately Class II (Intensive cultivation) (Hutton and Avalon soils are suitable for intensive cultivation), Class III (Moderate cultivation) and Class IV (Light cultivation/intensive grazing). The dominant land use within the project area is cultivated crops with subsidiary areas of grazing.

The fertility status of the soils is generally moderate with some requirement for lime (to counteract acidity) and phosphate fertiliser to achieve full cropping potential. Exchangeable base cations (potassium, calcium, magnesium) are present at sufficient levels and there is neither sodium nor salinity hazard. Texture is variable, from silt loam through silt, clay loam to clay.

Impact Assessment

During the establishment phase site clearing is necessary for the preparation surface infrastructure development (ventilations shafts) where vegetation will be removed and topsoil. When soil is removed, the physical properties are changed and the soils' chemical properties will deteriorate unless properly managed. Vehicles will drive on the soil surface during the establishment phase, thereby causing compaction of the soils. Bord and pillar method of mining could cause subsidence which would result in impacts to soil. The underground mining activities will cause a significant impact on the land capability of the identified soils causing subsidence and cracks (high extraction). The impacts of subsidence will be very high where 30 – 100 m mining is going to be taking place and will result in a complete loss of land capability and land use. Soil forms that will definitely be impacted on are Longlands, Katspruit, Avalon, Hutton, Arcadia, Glencore, Swartland, Westleigh, Pinedene and Kroonstad. There will be complete loss of the undermined wetland soils.

During rehabilitation and decommissioning phase, the potential impacts associated are the risk of hydrocarbon spills, erosion and compaction.

Recommendations

The following actions are recommended to minimise adverse effects of mining on soils and land capability:

- If possible topsoil should be stripped when the soil is dry, as to reduce compaction, adhering to clearly defined guidelines for stripping, with topsoil being saved separately.
- The soil stockpile should have a maximum height of 4 m to minimise adverse effects on soil chemical and physical properties.
- Stockpiles should be protected by a berm wall to prevent erosion of stockpiled material and deflect surface water runoff.
- Runoff must be controlled and managed by use of proper storm water management.
- Fuel and oils spills are common, remediate using commercially available emergency clean up kits and focus on awareness of prevention.
- Replaced soils require both physical and chemical amelioration as the actions of the soil removal; stockpiling and replacement result in soil compaction and dilution of the soil fertility. The actions that should be taken during the amelioration of soils include:
  - Soils must be ripped to ensure reduced compaction;
  - Restore soil fertility;
  - Incorporate fertilisers in to the planting zone; and
  - Apply maintenance dressing of fertilisers on an annual basis until the soil fertility cycle has been restored.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

1 Introduction

Sasol Mining (Pty) Ltd (Sasol Mining) holds mining rights for the Twistdraai Colliery: Thubelisha Shaft (TCTS) and the Vaalkop mining area, which were both incorporated into the regional Sasol Mining Right (Ref: MP30/5/1/2/2/138MR). It must be noted that no EMPr was compile for the Vaalkop mining right area even though a mining right was approved. Further to this, the mining right for the Trichardtsfontein Mine (Ref: MP30/5/1/2/2/10056MR) was ceded from Glencore Operations South Africa (Pty) Ltd in accordance with Section 11 of the Mineral and Petroleum Resources Development Act, 2002 (Act No. 28 of 2002) (MPRDA) to Sasol Mining. Sasol Mining is proposing that the Trichardtsfontein mining right area be incorporated into the regional Sasol Mining Right (Ref: MP30/5/1/2/2/138MR). Therefore all mining right areas will operate under a single mining right (Sasol Mining Right).

It is therefore required that the Environmental Management Programme Reports (EMPrs) for the above mentioned mining right areas be compiled (Vaalkop), consolidated and updated to reflect changes in the mining plans and methodologies and consider additional infrastructure requirements.

Digby Wells is proposing a submission in terms of the provisions of Section 102 of the Mineral and Petroleum Resources Development Act, 2002 (Act No. 28 of 2002) (MPRDA) and Regulation 31 of the National Environmental Management Act, 1998 (Act No. 107 of 1998) (NEMA) to obtain the required authorisation for both the amendment and consolidation process of the EMPrs (referred to in general as the Environmental Authorisation (EA) Amendment process). A basic assessment process will also be undertaken to obtain environmental authorisation for the construction and operation of the ventilation shafts. This will be undertaken as a consolidated process in accordance with the one environmental system.

Therefore the proposed process will be undertaken in accordance with the MPRDA and NEMA, in support of the required authorisations as listed below:

- Authorisation for the four ventilation shafts;
- Change in mining method for Trichardtsfontein and amendment of the Trichardtsfontein EMPr;
- Compilation of the EMPr for Vaalkop;
- Consolidation of Trichardtsfontein mining right into Sasol Mining Right; and
- Consolidation of the TCTS EMPr, Vaalkop EMPr and the Trichardtsfontein EMPr (referred to as the consolidation project).

The conservation of South African’s soil resources is essential for human survival. The mismanagement of land due to not classifying the soils and their capability/ potential correctly has led to loss of these resources through erosion and destabilisation of the natural systems. To identify soils accurately, it is necessary to undertake a soil survey, in accordance with standard procedures.

The aim of a soil survey is to provide an accurate record of the soil resources of an area. Land capability and land potential is then determined from these results. The objective of determining the land capability/ potential is to find and identify the most sustainable use of the soil resource without degrading the natural system.

Therefore soil mapping is essential to determine the types of soils present, their depths, their land capability and land potential. These results will then be used to give practical recommendations on preserving and managing the soil resources in light of the proposed Project. This report presents the findings of a specialist Soils, Land Capability and Land Use Assessment that forms part of the EMPr.

1.1 Project Background

The consolidation project area owned by Sasol Mining Twistdraai Thubelisha Colliery comprises three mining right areas namely TCTS, Trichardtsfontein and Vaalkop. Twistdraai Thubelisha Colliery is currently mining TCTS and proposes to start mining Trichardtsfontein within the next few months. Vaalkop mining area although a priority to Twistdraai Thubelisha Colliery will only start mining in 2029. To ensure the mines operate in a more efficient and effective manner Twistdraai Thubelisha Colliery intends to compile (Vaalkop) and consolidate all amended EMPrs into one merged EMPr.

The Trichardtsfontein project area is 3 170 ha in size, but only an area of approximately 1 382 ha will be undermined. The coal seam depth at Trichardtsfontein is estimated to be at an approximate depth of 140 – 160 m below surface. The infrastructure (including access shafts) will be on the adjacent mining property of Sasol Mining at the TCTS. However, two ventilation shafts (up and downcast) have been proposed to be construction on TCTS and two ventilation shafts (up and downcast) have been proposed to be construction on Trichardtsfontein which will assist in providing sufficient ventilation to the underground mining area.

The Vaalkop project area is approximately 8 600 ha in extent. The initial mining activities in this area will be conducted as green field operations as no existing infrastructure for coal mining exists in the area. It is foreseen that the Thubelisha conveyor could possibly be utilised. All mining activities will be conducted by means of underground mining operations, such as the bord-and-pillar and high extraction mining method. No infrastructure will be constructed on the Vaalkop project area as all required infrastructure will be located at the TCTS site. It is estimated that the coal seam depth at Vaalkop is approximately 80 - 120 m below surface.

The TCTS project area is 7 200 ha in size. The coal seam depth at TCTS is estimated to be at a depth of 140 - 170 m below the surface and the seam is approximately 2 – 5 m thick.

In all mining right areas will only mine the No 4 seam as it is the only seam of coal that is economically viable.

Due to the variation in depth of mining and coal seam an assumption has been made that mining will be undertaken between 30 m and 215 m. Therefore all impact assessments and specialist studies have assessed the impacts of mining utilising bord and pillar with high extraction at this depth.

Historically, a large part of the areas has been utilised as agricultural farmland, predominately under maize and soya beans, with stretches of grazing land.

1.2 Project Location and Description

The Thubelisha Project which includes the Trichardtsfontein Mine, Vaalkop and TCTS is located between the town of Trichardt and Bethal in the province of Mpumalanga (Figure 1-1). The town of Evander is 17 km to the West and Secunda is 10 km South West of the Trichardtsfontein and TCTS mining area. Vaalkop is located 5 km southeast of Bethal and 17 km southwest of Trichardt. The Thubelisha Project area and coal reserve are located within the Highveld East Magisterial District, the Gert Sibande District Municipality and the Govan Mbeki Local Municipality.

The Thubelisha Project is situated within a region that is characterised by coal mining activities and cultivation which includes maize cropping and grazing. The Isibonelo and Syferfontein coal mines are situated to the northwest of the Thubelisha Project area.

1.3 Mining Method

Due to the depth of the resource (i.e 30 - 215 m), underground mining will be used to access the ore body. A high extraction method of mining using bord-and-pillar mining with pillar extraction is currently being used at the TCTS and is proposed to be utilised at the Trichardtsfontein and Vaalkop Mines. In mechanised bord and pillar mining, extraction is achieved by developing a series of roadways (bords) in the coal seam connected by splits (cut-through) to form pillars. In high extraction mining, all the pillars are extracted to allow the roof to collapse in a controlled manner (also known stooping). Initially mining will occur to the east and west and move towards the north and south. Stooping will occur outside of the 1:100 floodlines and developed areas.

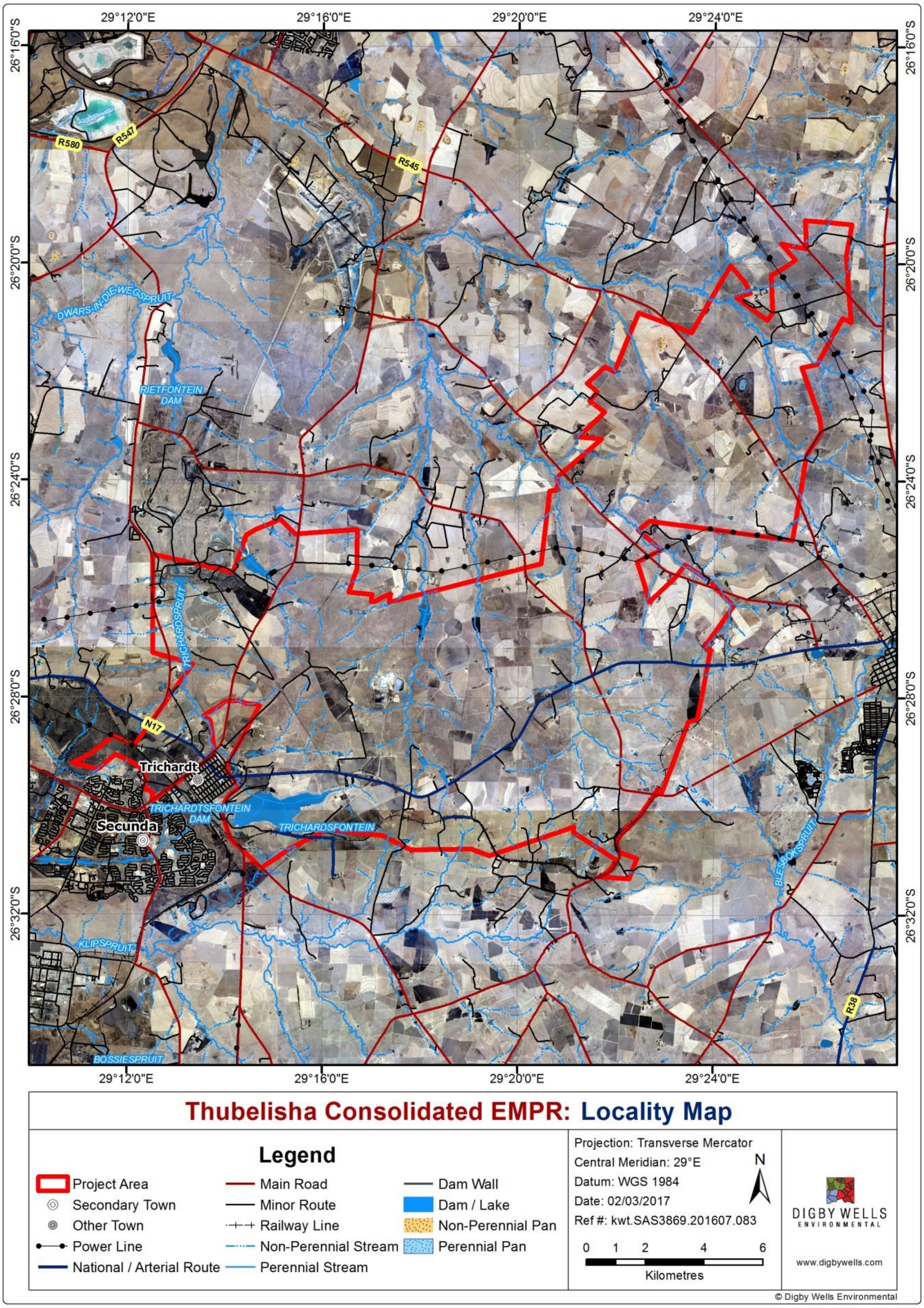


Figure 1-1: Local Setting Map for the Thubelisha Consolidate EMPr

2 Terms of Reference

The soil, land capability and land use assessment will compromise of the following activities:

- Review of all the existing soils information conducted by Earth Science Solutions (2008);
- Consolidating soils information (Thubelisha and Vaalkop);
- Updating Land capability, land type and land use maps;
- Soil survey: the soils occupying areas were surveyed during site visits. A hand soil auger was used to survey the soil types present and survey positions were recorded as waypoints. Description and categorisation of soils using the South African Soil Classification Taxonomic System (1991);
- Land capability: land capability was assessed from the soil classification;
- Land use/cover: present land use/cover was mapped in conjunction with the soil survey which included the following information:
  - Evidence of land misuse with special reference to problematic soils; and
  - Current land uses/covers associated with the respective project components.
- Describe soils in terms of soil fertility: 16 soil samples were collected; and
- Identify and assess potential impacts on soils resulting from the propose project using the prescribed impact rating methodology. Recommend mitigations measures to minimise impacts associated with the project.

3 Environmental Law Applicable to Study

The South African Environmental Legislation needs to be considered with the reference to the management of soil and land use which includes:

- Soils and land capability area protected under the National Environmental Management Act 107 of 1998, the Minerals Act of 2002 and the Conservation of Agricultural Resources Act 43 of 1983;
- The National Environmental Management Act 107 of 1998 requires that pollution and degradation of the environment be avoided, or, where it cannot be avoided be minimised and treated; and
- The Conservation of Agricultural Resources Act of 1983 states that the degradation of the agricultural potential of soil is illegal. The Conservation of Agricultural Resources Act 43 of 1983 requires that protection of land against soil erosion and the prevention of water logging and salinization of soils means of suitable soil conservation works to be constructed and maintained. The utilisation of marshes, water sponges and water courses are also addressed.

4 Details of the Author

The following is a list of the Digby Wells' staff who was involved in compilation of the soils assessment report for Thubelisha Consolidation Project:

Siphamandla Madikizela is a Soil Scientist, completed his MSc in Soil Science at University of KwaZulu-Natal and is a Professional Natural Scientist. Prior to his employment at Digby Wells Environmental, Siphamandla worked as an Assistant Plantation Manager at EcoPlanet Bamboo SA. He is the part of the Closure, Rehab and Soils Department at Digby Wells Environmental. His role involves conducting soil surveys; soil, land capability and land use environmental impact assessments; soil and agricultural potential studies; soil contamination assessments; interpreting results of soil samples; soil management plans and writing detailed scientific reports in accordance to local legislation and with the IFC. Siphamandla has worked in projects in South Africa, Democratic Republic of the Congo, Malawi and Mali. The Curriculum Vitae of the specialist involved in this study can be found in Appendix A.

5 Methodology

In order to complete the scope of work, there were a number of tasks which needed to be completed. These tasks are explained separately below.

5.1 Literature Review

Digby Wells conducted a desktop review of all the baseline data and findings related to the soil surveys undertaken by Earth Science Solutions. The following sources of information were reviewed and utilised for the compilation of this report:

- TCTS Soils and Land Capability Impact Assessment. Earth Science Solutions. March 2008; and
- Environmental Impact Assessment and Environmental Management Programme for the Trichardtsfontein Project. Digby Wells Environmental. February 2014.

5.2 Desktop Assessment

The desktop study was done before the site visit was undertaken in February and June 2017. The following data was obtained and studied to prepare for the site survey and the baseline reporting:

- Existing Land Type data was used to obtain generalised soil patterns and terrain types for the project site. Land Type data exists in the form of published 1:250 000 maps. These maps indicate delineated areas of relatively uniform terrain, soil pattern and climate (Land Type Survey Staff, 1972 - 2006). These maps and their accompanying reports provide a statistical estimate of the different soils that can be expected in the area.

5.3 Soil Classification

A detailed soil assessment of the soils present on the site was conducted during a field visit in February and June 2017. A free survey method was utilised which starts with a detailed physiographic aerial imagery interpretation and the surveyor actually walks most of the landscape, usually in traverses "across the grain", concentrating on the infrastructure areas. The surveyor chooses sample points in order to systematically confirm a mental model of the soil-landscape relationships, draw boundaries and determine map unit composition. A hand soil auger was used to determine the soil type and depth. Soils were investigated using a bucket auger to a maximum depth of 1.2 m or to the depth of refusal. Survey positions were recorded as waypoints using a handheld GPS. Other features such as existing open trenches were helpful to determine soil types and depth. The soil forms (types of soil) found were identified using the South African Soil Classification System (Soil Classification Working Group, 1991).

5.4 Soil Sampling and Analysis

Soil samples (0 to 0.6 m) of the dominant soil forms were collected at the project area. The samples were stored in plastic bags and sent to Intertek Agricultural Laboratory in Bapsfontein for analysis. Samples were analysed for indicators of acidity, fertility and texture as follows:

- Soil pH (KCl);
- Exchangeable cations (Ca, Mg, K, Na) (ammonium acetate extraction);
- Phosphorus (Bray No. 1 extractant);
- Organic Carbon; and
- Soil texture (Sand, Clay and Silt).

Soil texture is simply defined as the relative proportion of sand, silt and clay particles found in the soil. The relative proportions of these 3 fractions (clay, sand and silt) as illustrated by the red arrows in Figure 5-1 determines 1 of 12 soil texture classes for examples sandy loam, loam, sand, sandy clay loam etc. The different texture class zones are demarcated by the thick black line in the diagram. The green zone can be used as a guideline for moderate to high agricultural potential, but need to be evaluated together with other soil properties.

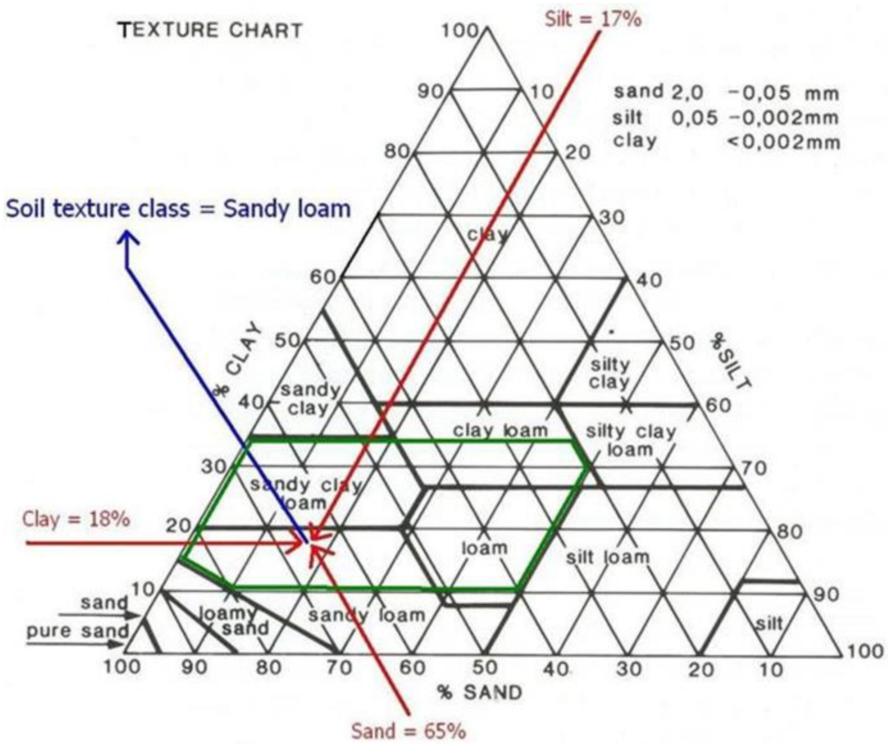


Figure 5-1: The Soil Textural Triangle

(Source: SASA, 1999)

5.5 Land Capability

Land capability was determined by assessing a combination of soil, terrain and climate features. Land capability is defined by the most sustainable land use under rain-fed conditions. The approach is contained in the Coaltech Research Association and the Chamber of Mines of South African Guidelines for the Rehabilitation of Mined Land, 2007. These Guidelines recommend the following classes; arable, grazing, wilderness and wetland. The following criteria are used to define the classes:

- **Arable**: The soil depth exceeds 0.6 m, the soil material is not sodic or acidic and slope percentage is such that when multiplied by the soil erodibility factor K, the product does not exceed a value of 2.0;
- **Grazing**: The soil depth is less than 0.6 m but more than 0.25 m; and
- **Wilderness**: The soil depth is less than 0.25 m but more than 0.15 m.

5.6 Land Use

The current land use was identified by aerial imagery and by on-site inspection. The land use can be classified in the following categories:

- Plantations;
- Natural;

- Waterbodies;
- Mines;
- Urban built-up; and
- Cultivated.

6 Assumptions

The following assumptions have been made:

- The information provided in this report is based on information gathered from fieldwork for Vaalkop area undertaken on the February and June 2017;
- As per scope of work, only the Vaalkop Project area was delineated and surveyed by Digby Wells;
- The information contained in this report is based on auger points taken and observations on site; and
- Review of all the existing soils information conducted by Earth Science Solutions (2008).

7 Literature Review: Thubelisha (Earth Science Solutions, 2008)

7.1 Dominant Soil Forms

The major soil forms found on the site were Hutton, Clovelly, Griffin, Glenrosa, Mispah, Arcadia, Mayo, Milkwood, Pinedene, Glencoe, Dresden, Avalon, Bloemdal, Westleigh, Rensburg, Bonheim, Kroonstad, Longlands and Katspruit. The soils range from good quality agricultural soils with moderate dryland cropping potential and moderate to good irrigation potential, to shallow, poor quality soils those are at best useful as grazing lands. The free-draining soils on the middle and upper mid-slopes (Clovelly, Hutton, Griffin and Glencoe) are generally derived from the sandstone and shales of the Ecca Group. Dark red and brown soils are associated with the colluvial derived soils that accumulate in the valley bottoms. Dark grey to mottled colour, clay rich colluvium and hydromorphic soils dominate the low lying, gently sloping stream/river and pan environments.

7.2 Soil Chemical and Physical Characteristics

Representative soil samples from the different soil forms were taken and analysed for both chemical and physical parameters. The soil samples submitted were chosen based on the host materials from which they are derived:

- Soil pH ranged between 4.40 and 6.90 (slightly acidic) with a base status ranging from mesotrophic to dystrophic;
- Calcium and Magnesium had moderately good to high levels;

- Potassium, Phosphorus and Sodium had low levels when compared to Calcium and Magnesium;
- Organic carbon ranged between 0.16 to 1.47 %, regarded as sufficient for moderate to good agricultural production;
- Levels of Zinc were generally moderate to slightly low;
- The soils in the area showed no visibility signs of being either highly sodic or highly saline;
- There are no indications of either toxic elements or major deficiencies of nutrients that are likely to limit natural plant growth in the soils within the area;
- Topsoil clay percentages range from 12 to 28 % on the sand loams and silty loams;
- Subsoil clay percentages range from 30 to 60 %;
- Infiltration rate ranges from 5 to 8 mm/hr; and
- Water holding capacity between 80 to 160 mm/m.

7.3 Land Capability

Approximately 98.10 ha is considered to be arable land potential, 3620.35 ha is grazing land, 4176.99 ha is wilderness and 2460.72 ha is wetland. The land capable for sustaining arable crop production will require the utilisation of the deeper (>750 mm) well drained, red (Hutton) and yellow-brown (Clovelly and Griffin) soils that occur on the mid-slope and upper mid-slope positions. Deeper hydromorphic soil (Avalon and Pinedene) forms are capable of sustaining crop production. The areas that are classified as grazing land are generally confined to the shallower and transitional zone. Areas classified as wilderness land are associated with the shallower and rockier soils. The wetland soils are defined in terms of hydromorphic soil criteria and these soils are generally dark grey to black in the topsoil horizons.

7.4 Thubelisha (TCTS) Environmental Management Plan

The aim of the soil management and rehabilitation plan is to apply best practice to stripping and storage of utilisable soil form areas that are to be impacted to maintain the soils that have been stockpiled and those in-situ soils that might be affected by the operation.

- Soil stripping and stockpiling;
  - Over shaft areas all usable soil should be stripped. Strip and stockpile red/brown and yellow soils separately from the grey, black and heavy structured soils. Replace soils to appropriate soil depths;
  - Over area of structures and soft overburden stockpiles strip the top 0.3 m of usable soil;

  - Over area of coal and hard overburden stockpiles strip usable soil to a depth of 0.75 m in areas of arable soils and between 0.3 and 0.5 m in areas of soils with grazing and wilderness land capability. Stockpile red/brown, yellow and black soils separately;
  - Over area of access roads and conveyor servitudes, keep compaction to a minimum.
- Monitoring and maintenance of in-situ and rehabilitated soils;
  - Soil sampling should be carried out annually until the levels of nutrients, specifically phosphorus and potassium are at the required level (approximately 20 and 120 mg/kg respectively). Soil samples should be analysed for the following parameters: pH (KCl), EC, Cations (Ca, Mg, Na and K), Cation Exchange Capacity (CEC), Phosphorus (Bray1), Zinc, Clay % and Organic Carbon Content.
- Soil replacement
  - Replace overburden from stockpiles, followed by the subsoils. Spread the soils evenly over the rehabilitated area to achieve pre-mining topography and compacted;
  - Structured soils that might have been disturbed, they should be levelled, ripped and diced to break-up any induced structure (soil clods); and
  - Add the topsoil's and cultivate, the fertiliser should be added using a standard fertiliser spreader and should be applied in small quantities at regular intervals.
- Fertilisation
  - Commercial fertiliser should be added to the soil at a rate of 200 kg/ha before re-vegetation.

8 Findings: Vaalkop

The land type data gathered suggested that the dominant land types on site were Bd4, Ea17 and Ea20 (Figure 8-2). Further information related to the soil within the project area is discussed in Section 8.1 below. The project area is dominated by Hutton (Red), Avalon (Yellow-brown), Mispah, Rensburg, Arcadia, Swartland, Katspruit, Glencoe, Kroonstad, Longlands and Westleigh soil forms as shown in Figure 8-1. These soils are described in more detail in the sections below. The project site is dominated by the presence of soils suited to agriculture such as Hutton and Avalon and the remainder of the project area consists of soils with low agricultural potential and wetland soils.

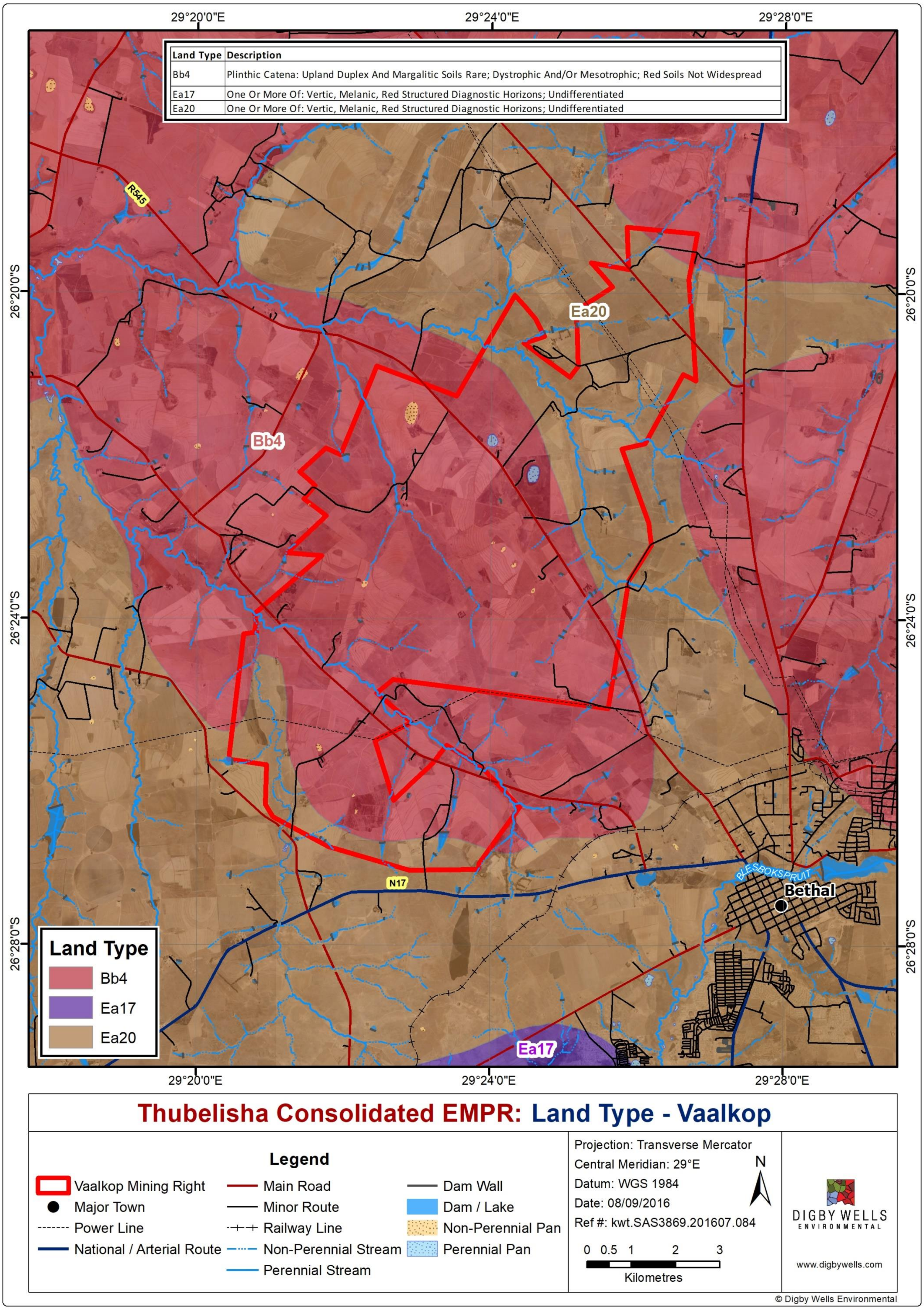
8.1 Land Type and Soil Forms

Table 8-1 shows dominant land types and soil forms found in the Vaalkop area.

Table 8-1: Dominant Land Types and Soil Forms

Land Type	Soil Forms	Description	Geology
Bb4 (5572.0 ha)	Avalon, Hutton, Glencoe, Mispah, Longlands, Katspruit, Rensburg, Arcadia and Swartland	The effective depth of these soils is greater than 0.6 m except for shallow soils. The clay content of the soils range between 15 and 20 %.	Shale, sandstone, clay and conglomerate of the Ecca Group, Karoo Sequence, dolerite, occasional felsitic lava of the Rooiberg Group and the Transvaal Sequence
Ea20 (2424.5 ha)	Arcadia, Swartland, Glenrosa, Avalon, Rensburg, Westleigh	The effective rooting depth of the dominant soils is below 0.6 m and soils contain clay content above 30 %	Dolerite, sandstone, grit and shale of the Ecca Group, Karoo Sequence.

Figure 8-1: Examples of soils found on the Vaalkop site (Glencoe, Rensburg, Longlands, Bonheim, Arcadia and Hutton, respectively)



Land Type	Description
Bb4	Plinthic Catena: Upland Duplex And Margalitic Soils Rare; Dystrophic And/Or Mesotrophic; Red Soils Not Widespread
Ea17	One Or More Of: Vertic, Melanic, Red Structured Diagnostic Horizons; Undifferentiated
Ea20	One Or More Of: Vertic, Melanic, Red Structured Diagnostic Horizons; Undifferentiated

Figure 8-2: The Land Type Map for the Vaalkop Area (Land Type Survey Staff, 1976 – 2006)

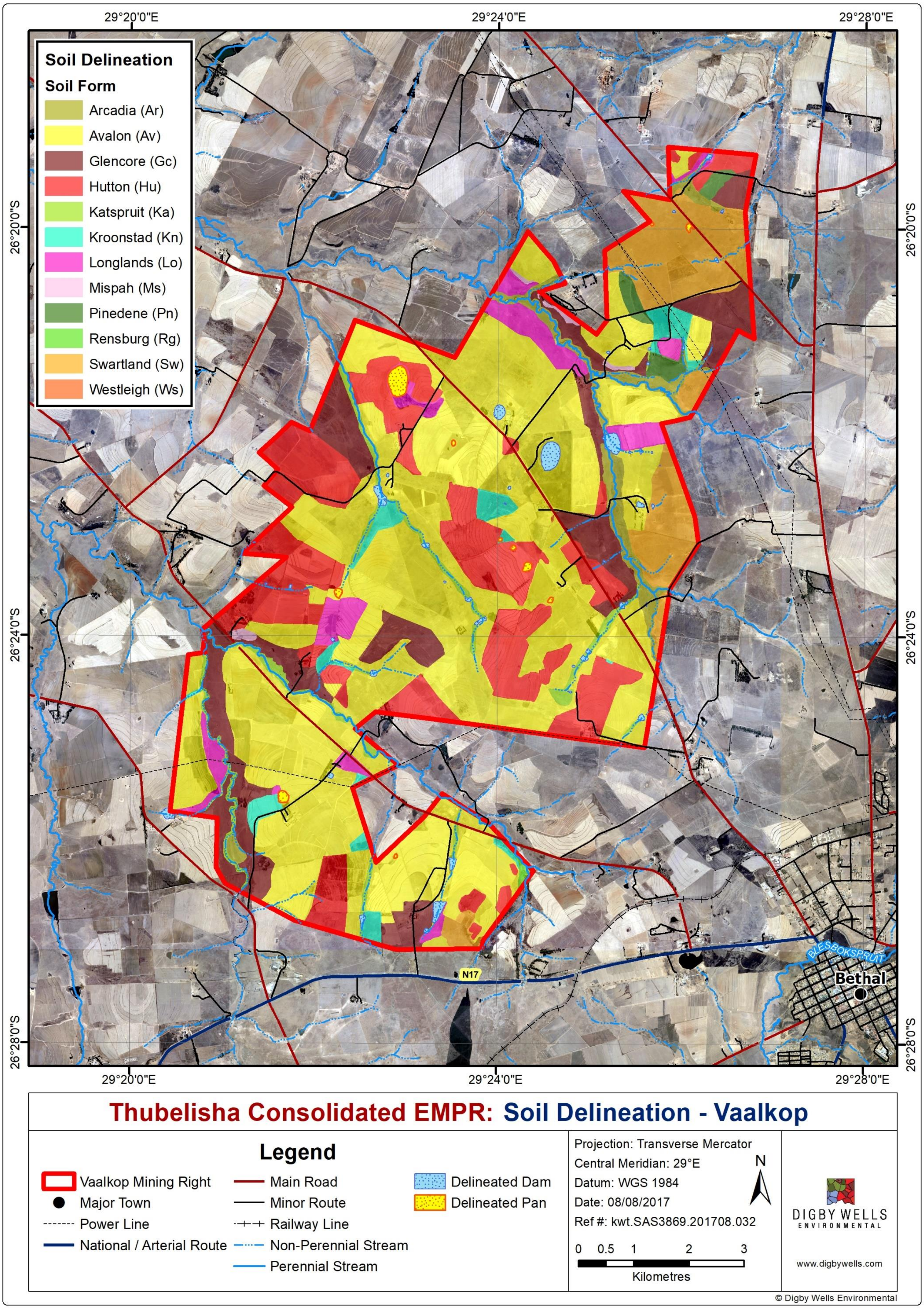


Figure 8-3: Soil distribution map for the Vaalkop area

8.1.1 Hutton Form

The Hutton soil form consists of an orthic A and red apedal B over unspecified material. These soils are well drained, usually slightly acidic, and have a low cation exchange capacity (CEC) due mainly to clay mineral composition (kaolinite, iron oxides) and sometimes low clay content. This soil form was identified in relatively flat landscape positions and has high arable potential and high value for use as topsoil, having favourable structure (weak blocky to apedal) and consistence (slightly firm to friable).

8.1.2 Avalon Form

The Avalon soil form consists of orthic topsoil, on a yellow-brown apedal B, over a soft plinthic B horizon. Avalon soils are freely draining and chemically active. Manganese and iron oxides accumulate under conditions of a fluctuating water table forming localised mottles or soft iron concretions of the soft plinthic B horizon. Mottling in the samples found within the study site was yellow-brown in colour and occupied at least 10 % of the horizon (Fey *et al*., 2010). Avalon soils are highly suitable for crop production, particularly for growing maize. Fey *et al*. (2010) explains that this is due to the freely draining nature of the soil and soft plinthic B horizon which traps water and makes it available for root uptake.

8.1.3 Rensburg Form

The Rensburg soil form is characterized by dark brown/black Vertic topsoil over a G-horizon. Found exclusively with the wetland and vlei areas within the floodplain and riverine environments. The hydromorphic nature of these soils renders them susceptible to compaction and erosion. Rensburg soil forms are high in clay and have a sticky texture. These soils develop surface cracks and crusts in the dry state, and slickensides due to swelling pressures caused by water uptake. The G horizon is permanently wet, has still retained some clay and iron oxides or mottling and has a grey or gleyic colour pattern. Vertic soils are difficult to work with for crop production due to their shrink and swelling properties. However, success has been ascribed for the cotton plant as its rooting system can withstand shrinking and swelling movement in the soil.

8.1.4 Arcadia

The Arcadia soil form consists of a deep vertic A over unspecified material. If the material at depth is gleyed clay, then the soil form is Rensburg. These soils are black in colour and extremely physically active. They have shrink-swell properties (Fey *et al*., 2010). With the start of the rainy season, Arcadia soils are dry and cracked and water infiltration is high bypassing the soil body and potentially recharging the groundwater or downslope soils. When it rains, the soil swells and the cracks close and infiltration rate slows (Fey *et al*., 2010). These soils hold large amounts of water which often are not available to crops. Arcadia soils can accommodate a selected composition of vegetation such as grazing vegetation for cattle or strong rooted crops such as cotton or sunflower.

8.1.5 Swartland Form

The Swartland soil form consists of an orthic A over pedocutanic B over soft decomposing rock. Saprolite occurs within 0.5 m of the lower limit of the pedocutanic B horizon and the saprolite is weakly weathered.

8.1.6 Katspruit Form

The Katspruit soil form consists of an orthic A over a diagnostic G horizon. The G horizon it is saturated with water for long periods unless artificially drained is dominated by grey colour and lacks saprolitic and plinthic character. This soil form usually indicates the presence of seasonal or permanent wetlands and thus signifies a wetland land capability class.

8.1.7 Glencoe Form

The Glencoe soil form consists of an orthic A, and yellow-brown apedal B over a hard plinthic B horizon (iron oxide cemented pan, known colloquially as mgubane or ouklip). Glencoe soils are low to moderately suitable for crop production depending on the depth of the hard plinthic horizon. For shallow Glencoe soils, the impermeable plinthic material can impede rooting depth and cause periodic waterlogging (Fey *et al*., 2010).

8.1.8 Mispah Form

The Mispah soil form consists of an orthic A over hard rock material. These soils are shallow, have a low agricultural potential, usually a high erosion hazard and have limited rooting depth.

8.1.9 Kroonstad Form

The Kroonstad soil form consists of an orthic A over an E horizon overlying a G horizon. Saturation of the G horizon results in protracted anaerobic conditions resulting in reduction of ferric oxides which results in the grey colour (Fey *et al*., 2010). Intermittent wetness in the E horizon and even more protracted wetness in the G horizon can prove problematic and drainage of some kind is usually required.

8.1.10 Longlands Form

The Longlands soil form consists of Orthic topsoil on an E horizon, over soft plinthic B subsoil. The E horizon is distinguishable by criteria, namely;

- Grey, pale yellow or white matrix colours;
- Being intermittently saturated with water;
- The depletion of iron oxides, clay and organic matter; and
- Being loose when wet, and hardens and becomes brittle when dry.

The intermittent saturation in E horizon results in periodic anaerobic conditions in Longlands soil form, causing dissolved iron oxides to be deposited to an insoluble state in the form of mottling of the soft plinthic B horizon. From a land use point of view, the Longlands soil form has a low to moderate agricultural potential. The waterlogged, anoxic conditions can present problems with rooting depth. Artificial drainage can mitigate high saturation and the application of lime and gypsum can alleviate toxicity and improve the rooting depth of crops such as maize (Fey *et al*., 2010).

8.1.11 Westleigh Form

The Westleigh soil form consists of an orthic A over soft plinthic B horizon. The soft plinthic layer forms as a result of intermittent wetness due to a fluctuating water table typically associated with distinct dry and wet seasons. Iron and manganese migrate and precipitate as mottles and concretions or nodules. Westleigh soils are normally not considered suitable for cultivation.

Dominant soils form included Hutton, Avalon, Rensburg, Arcadia, Westleigh, Glencoe, Longlands, Kroonstad and Katspruit. Most of the soil forms have a low agricultural potential and are used mainly for grazing purposes (livestock farming).

8.2 Land Capability

Land capability is determined by assessing a combination of soil, terrain and climate features. The dominant land capability classes in the Vaalkop area were Class II (**Intensive cultivation, 5572 ha**) and Class IV (**Light cultivation/intensive grazing, 2424 ha**) (Figure 8-4). The ensuing paragraphs list in detail the limitations used to define the three classes.

8.2.1 Class II: Intensive Cultivation

Class II land capability coincides with the Hutton soils. These soils are well drained, easily managed and have high agricultural potential. Land in Class II has 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; and

- 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.

8.2.2 Class IV: Light Cultivation/ Intensive Grazing

Land in Class IV has severe limitations that restrict the choice of plants, require very careful management or both; it may be used for cultivated areas, 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. Use for cultivated crops in Class IV is limited as a result of the effects of one or more permanent features such as:

- Steep slopes;
- Shallow soils;
- Low-water holding capacity; and
- Moderately adverse climate and severe susceptibility to water or wind erosion.

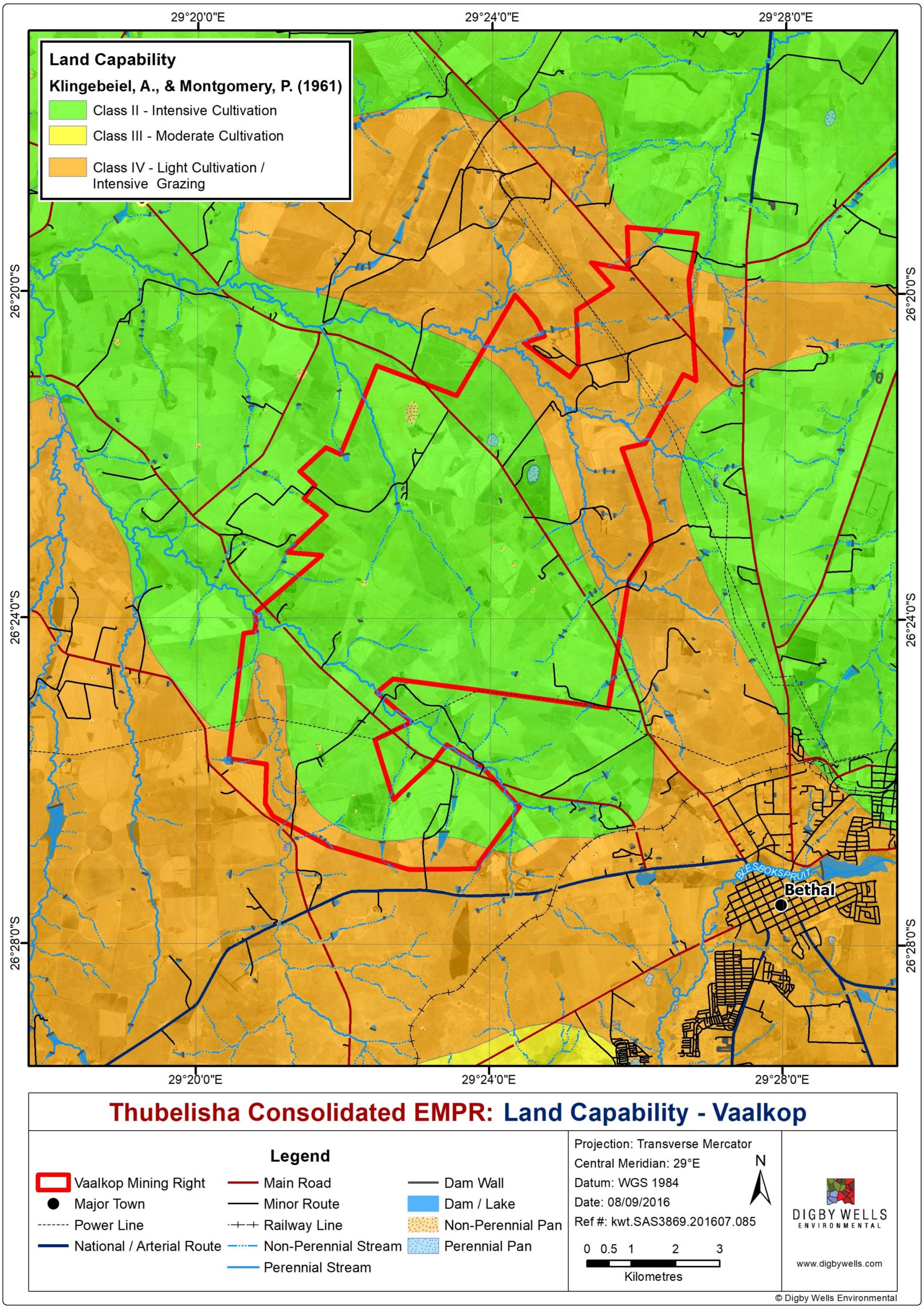


Figure 8-4: The Land Capability Map for the Vaalkop Area (Land Type Survey Staff, 1976 – 2006)

8.3 Land Use

The most dominant land uses as shown in Figure 8-5 are followed cultivated areas (maize and soya beans), grassland and low shrubland (grazing), urban areas (farms) and water bodies (rivers and wetlands).

The land use is classified as follows:

- Cultivated areas (**4026.8 ha**);
- Thicket (**97.2 ha**);
- Grassland and low shrubland (**3263.2 ha**);
- Urban Areas (**15.4 ha**); and
- Water bodies (**517.5 ha**).

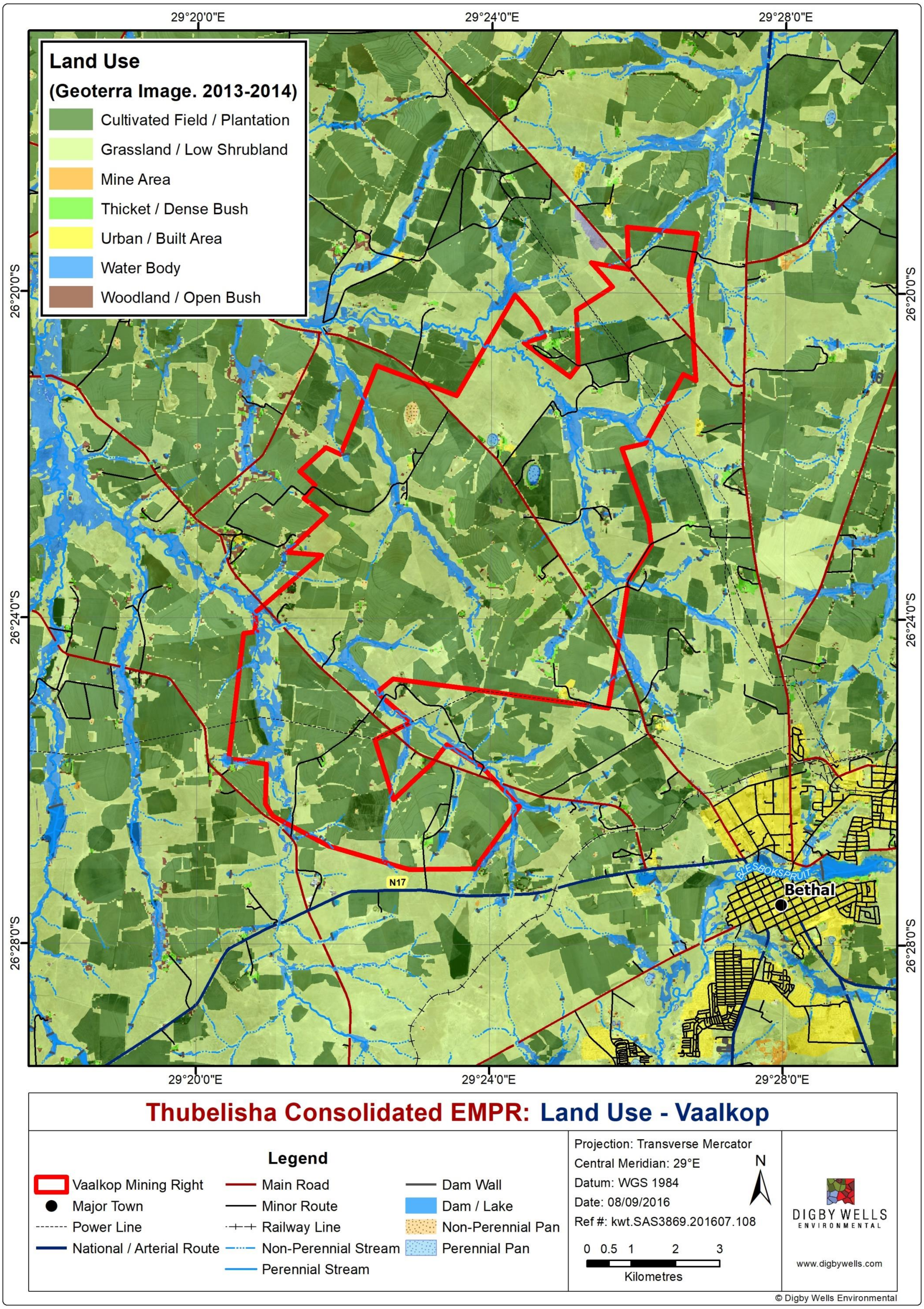


Figure 8-5: The Land Use Map for the Vaalkop Area

8.4 Soil Chemical and Physical Characteristics

The results of soil analysis are presented in Table 8-2 and as a basis for interpreting these data some local soil fertility guidelines are presented in Table 8-3. A total of 16 soil samples were collected from different soil profiles. The analytical determinations were conducted in the laboratories of the Intertek Agricultural Services in District Bapsfontein, Johannesburg. The objective of this section of the study was to characterise the soil physico-chemical properties and soil properties assessed included:

- Chemical properties (pH, OC, exchangeable bases, sulphur and phosphorus); and
- Soil texture (clay, silt and sand).

Table 8-2: Soil Physico-Chemical Properties

Land Ref	Soil Form	pH (KCl)	P (Bray1)	Na	K	Ca	Mg	S	C	Clay	Silt	Sand	Soil Texture
			mg/kg						%				
135	Avalon	5.1	2.4	46.3	8.2	215.3	56.6	5.0	0.6	17	70	13	Silt loam
141	Avalon	4.4	1.9	32.6	7.3	387.5	85.2	8.2	0.3	19	74	7	Silt loam
153	Hutton	5.1	4.5	38.7	7.0	633.8	217.0	7.3	0.6	21	64	15	Silt loam
155	Hutton	4.7	3.2	52.3	9.4	540.9	117.3	9.3	0.4	21	65	14	Silt loam
169	Swartland	5.0	1.2	123.7	25.9	2930.0	1490.4	30.0	1.4	39	30	31	Clay loam
190	Hutton	4.0	2.8	33.2	4.2	1205.0	621.9	12.7	0.2	15	78	7	Silt loam
198	Hutton	5.6	5.2	38.1	6.5	355.4	150.7	3.9	0.2	13	80	7	Silt loam
219	Avalon	4.2	7.3	30.7	9.7	459.0	93.6	6.3	0.4	17	74	9	Silt loam
225	Avalon	4.5	7.2	37.4	6.7	194.0	49.3	4.6	0.4	5	74	21	Silt loam
254	Hutton	6.4	0.5	173.4	170.7	2353.9	1217.5	44.1	0.1	44	40	16	Clay
235	Arcadia	7.1	0.9	106.7	536.9	2507.5	3036.5	61.7	0.8	52	19	29	Clay
483	Avalon	4.4	1.9	77.8	194.8	696.2	830.9	23.2	0.5	16	73	11	Silt loam
316	Glencoe	4.5	1.1	31.6	9.6	437.3	171.5	12.9	0.4	12	73	15	Silt loam
255	Hutton	6.3	36.2	48.0	20.0	738.1	216.4	19.7	0.2	4	86	10	Silt
464	Hutton	4.1	3.2	83.9	6.3	308.7	61.3	15.0	0.4	4	80	16	Silt
820	Kroonstad	5.4	8.2	130.4	10.3	1083.0	243.7	20.2	0.6	24	64	12	Silt loam

8.4.1 Soil pH

The soil pH is determined in the supernatant liquid of an aqueous suspension of soil after having allowed the sand fraction to settle out of suspension. Soil pH has a direct influence on the plant growth:

- Through the direct effect of the hydrogen ion concentration on nutrient uptake;
- The mobilisation of toxic ions such as aluminium which restrict plant growth; and
- Indirect impacts include the effect on trace nutrient availability.

The soil pH ranged from 4.0 to 7.1, thus the soils are acidic to neutral when compared to the guidelines in Table 8-3. Soils with pH below 5 might be due to the acidic nature of the parent material from which the soils were derived and high rate of leaching of the nutrient down profile. Addition of agricultural lime would be required for soils with pH below 5 to remedy soil acidity and increase plant growth.

8.4.2 Exchangeable cations

The levels of the basic cations Ca, Mg, K and Na are determined in soil samples for agronomic purposes through extraction with an ammonium acetate solution. In general, the amounts of exchangeable cations normally follow the same trend as outlined for soil pH and texture. For most soils, cations follow the typical trend Ca>Mg>K>Na.

Calcium ranged from 194 to 2930 mg/kg and Magnesium ranged from 49.3 to 3036.5 mg/kg, these levels in the soil were generally adequate for crop production and these nutrients are not limiting any production on the site or not considered as toxic. Thus there is no need to add sources as they might suppress levels of potassium during nutrient uptake by plants.

Potassium levels are very low when compared to the soil fertility guidelines. High rainfall intensity, leaching and underlying parent material may have been responsible for these low values. The potassium uptake by plants is further decreased by the dominance of cation complex by high calcium and magnesium levels. Potassium fertiliser application will be required on significant portions to increase the levels for good crop production.

Sodium levels of the soils are low and tolerable to plant growth and development. Soil dispersion is unlikely to occur and cause dense structure and drainage problems (de Villiers *et al*., 2003) except for 2:1 clay soils like Rensburg, Arcadia and Swartland. No serious chemical issues such as soil salinity or sodicity occur on site.

Soil samples collected show the profile of Ca>Mg>Na>K concentrations.

8.4.3 Phosphorus

The soil phosphorus levels are very low, ranging from 0.5 to 36.2 mg/kg. The low values of phosphorus may be due to phosphorus fixation and the acidic nature of the soil. Phosphorus fertilisation will be required to establish good crop stand and growth at the area. An application of excess phosphorus will lead to long-term improvement in soil fertility

8.4.4 Organic carbon

Soil organic carbon provides an indication of organic matter content in a soil. Levels above 2 to 3 % are considered moderate to high according to du Preez *et al* (2010). The soil organic carbon content of the soil on the area ranged from 0.1 to 1.4 % across and these levels are relatively low. An external nutrient input source will be required where deficiency of organic matter occurs.

8.4.5 Soil texture

The particle size distribution of the soil sampled of the area was classed into the percentages of sand, silt and clay present. The clay fraction ranged from 4 to 52 %, sand from 7 to 31 % and silt from 18 to 86 %. The textural class obtained from plotting the three fractions on a textural triangle (Figure 5-1). The soils can describe as texturally variable, containing a mixture of silt loam, clay loam and clay.

Table 8-3: Soil Fertility Guidelines (Fertiliser Association of South Africa, 2003)

<table>
<tr><th colspan="6">Guidelines (mg per kg)</th></tr>
<tr><th colspan="3">Macro Nutrient</th><th colspan="2">Low</th><th>High</th></tr>
<tr><td colspan="3">Phosphorus (P)</td><td colspan="2"><5</td><td>>35</td></tr>
<tr><td colspan="3">Potassium (K)</td><td colspan="2"><40</td><td>>250</td></tr>
<tr><td colspan="3">Sodium (Na)</td><td colspan="2"><50</td><td>>200</td></tr>
<tr><td colspan="3">Calcium (Ca)</td><td colspan="2"><200</td><td>>3000</td></tr>
<tr><td colspan="3">Magnesium (Mg)</td><td colspan="2"><50</td><td>>300</td></tr>
<tr><th colspan="6">pH (KCl)</th></tr>
<tr><th>Very Acid</th><th>Acid</th><th>Slightly Acid</th><th>Neutral</th><th>Slightly Alkaline</th><th>Alkaline</th></tr>
<tr><td><4</td><td>4.1-5.9</td><td>6-6.7</td><td>6.8-7.2</td><td>7.3-8</td><td>>8</td></tr>
</table>

The soils were classified as acidic with low phosphorus, potassium and sodium levels. Also organic carbon levels were low. Low levels of phosphorus, potassium and organic carbon can limit the land capability of the soils.

8.5 Agricultural Potential

Among the dominant soils in Table 8-4, the Hutton and Avalon forms have moderate to high agricultural potential. The remainder of the soils have low agricultural potential.

Table 8-4: Agricultural Potential for Soils

Soil Form	Depth	Agricultural Potential
Hutton	0 – 1.2	High
Avalon	0 – 0.8	Moderate to high
Glencoe	0 – 0.5	Low to moderate
Kroonstad	0 – 0.5	Low to moderate
Mispah	0 – 0.3	Very low
Arcadia	0 – 0.4	Very low
Katspruit	0 – 0.4	Very low
Rensburg	0 – 0.3	Very low
Longlands	0 – 0.4	Low to moderate
Swartland	0 – 0.6	Low to moderate
Westleigh	0 – 0.4	Low

8.6 Dryland Crop Production

The largest part of the project area is currently used for crop production. According to the Department of Agriculture in co-operation with ARC-Grain Crops Institute; 350 to 450 mm of rain per annum is required for successful maize production.

The dryland production potential of the Rensburg, Mispah, Swartland soils is very poor; while that of the Avalon and Glencoe is considered moderate. The dryland production potential of the Hutton soils is moderate to high. Due to low nutrient status, fertilisers would be required to increase the productivity.

8.7 Irrigated Crop Production

The irrigation potential of the arable soils (Hutton and deep Avalon) is moderate to good. The remainder of the soils are generally drainage impaired and drainage control would be required.

9 Consolidation (Thubelisha and Vaalkop)

9.1 Land Type and Soil

The land type data gathered during the scoping phase suggested that the dominant land types on site were Bb4, Ea17 and Ea20 (Figure 9-1).

Table 9-1: Dominant land type soil forms

Land Type	Soil Forms	Description	Geology
Bb4	Avalon, Hutton, Glencoe, Mispah, Longlands, Katspruit, Rensburg, Arcadia and Swartland	The effective depth of these soils is greater than 0.6 m except for shallow soils. The clay content of the soils range between 15 and 20 %.	Shale, sandstone, clay and conglomerate of the Ecca Group, Karoo Sequence, dolerite, occasional felsitic lava of the Rooiberg Group and Transvaal Sequence
Ea17	Arcadia, Swartland, Glenrosa, Avalon, Rensburg, Westleigh	The effective rooting depth of the dominant soils is below 0.6 m and soils contain clay content above 30 %	Dolerite, sandstone, grit and shale of the Ecca Group, Karoo Sequence.
Ea20	Arcadia, Swartland, Glenrosa, Avalon, Rensburg, Westleigh	The effective rooting depth of the dominant soils is below 0.6 m and soils contain clay content above 30 %	Dolerite, sandstone, grit and shale of the Ecca Group, Karoo Sequence.

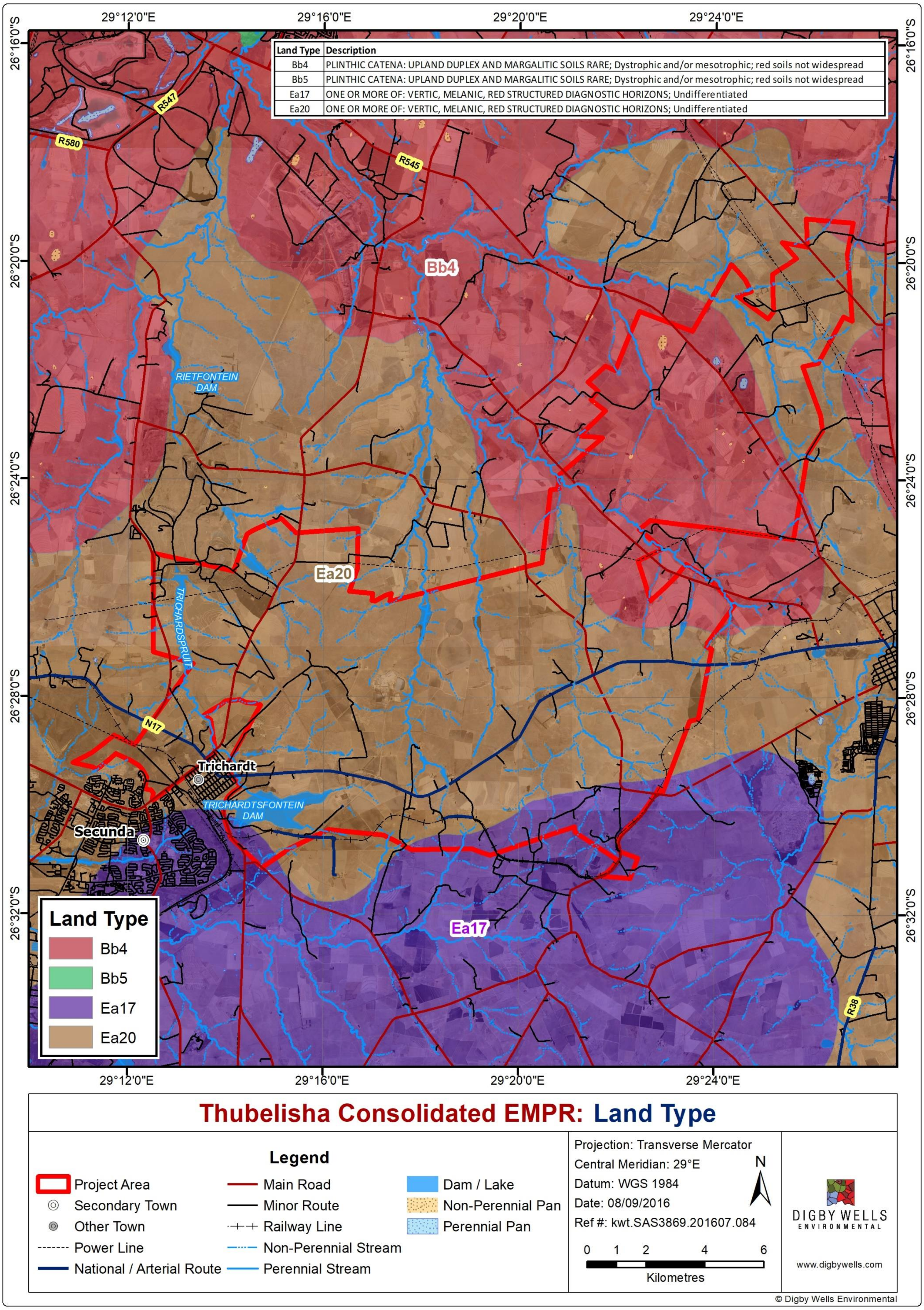


Figure 9-1: The Land Type map for the Thubelisha Consolidated EMPr (Land Type Survey Staff, 1976-2006)

9.2 Land Capability

Land capability is determined by assessing a combination of soil, terrain and climate features. The dominant land capability classes are Class II (**Intensive cultivation, 5 571.96 ha**), Class III (**Moderate cultivation, 1 161.50 ha**) and Class IV (**Light cultivation/intensive grazing, 16 583.34 ha**) (Figure 9-2). The ensuing paragraphs list in detail the limitations used to define the three classes.

9.2.1 Class II: Intensive cultivation

Class II land capability coincides with the Hutton soils. These soils are well drained, easily managed and have high agricultural potential. Land in Class II has 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; and
- 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

9.2.2 Class III: Moderate cultivation

Land in Class III has more severe limitations that reduce the choice of plants or require special conservation practices or both. Land 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. The number of practical alternatives for average farmers is less than that for soils in Class II. Limitations restrict, singly or in combination, the amount of clean cultivation, time of planting, tillage, harvesting and choice of crops. Limitations may result from the effects of one or more of the following:

- Moderately steep slopes;
- High susceptibility to water or wind erosion or severe adverse effects of past erosion;

- 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 clay-pan that limits the rooting zone and water storage;
- Low water-holding capacity;
- Low fertility not easily corrected;
- Moderate salinity or sodicity; and
- Moderate climatic limitations.

9.2.3 Class IV: Light cultivation/Intensive grazing

Land in Class IV has severe limitations that restrict the choice of plants, require very careful management or both; it may be used for cultivated areas, 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. Use for cultivated crops in Class IV is limited as a result of the effects of one or more permanent features such as:

- Steep slopes;
- Shallow soils;
- Low-water holding capacity; and
- Moderately adverse climate and severe susceptibility to water or wind erosion.

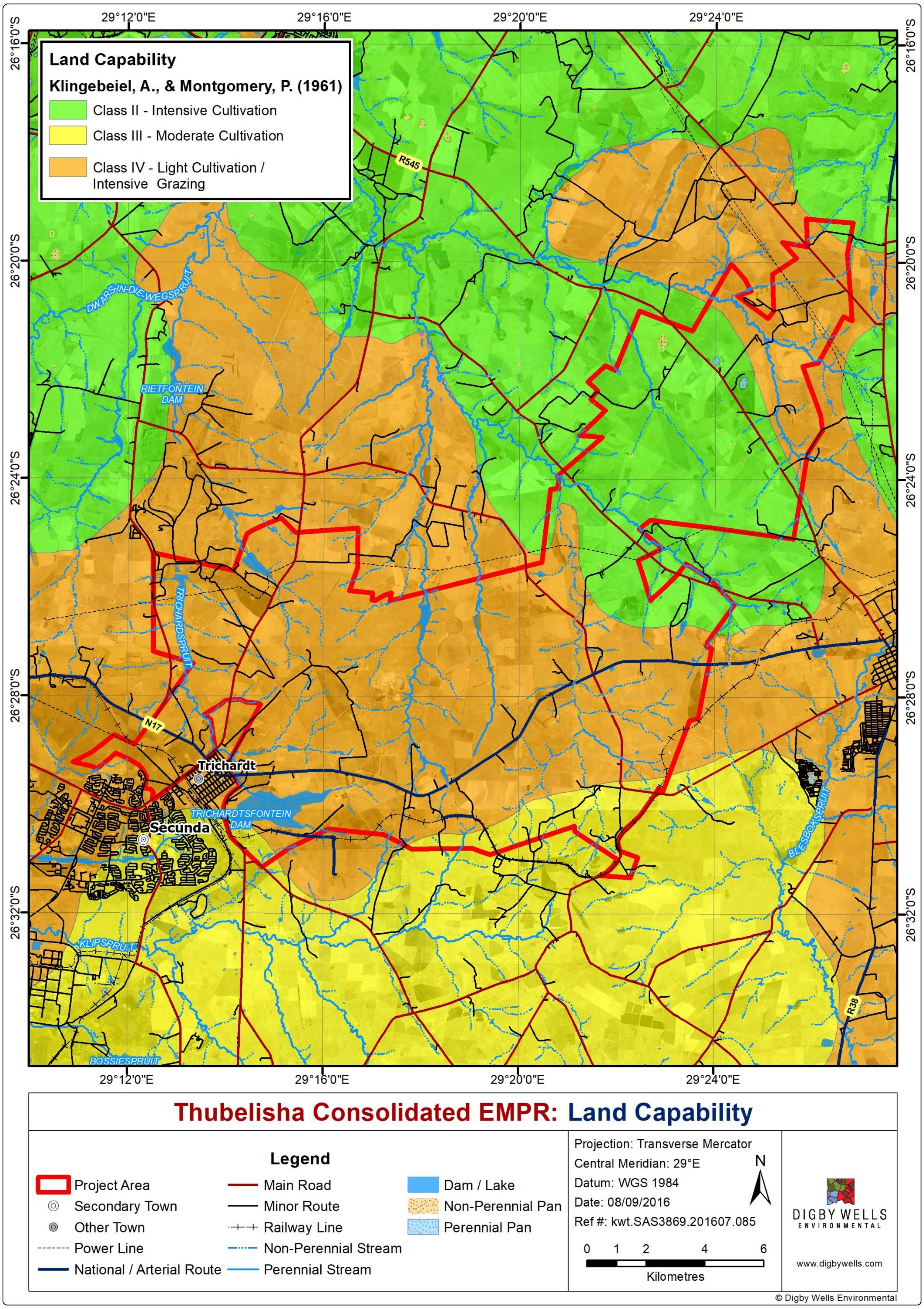


Figure 9-2: The Land Capability map for the Thubelisha Consolidated EMPr (Land Type Survey Stuff, 1976-2006)

9.3 Land Use

The most dominant land uses as shown in Figure 9-3 are followed cultivated areas (maize and soya beans), grassland and low shrubland (grazing), mine areas, urban areas and water bodies.

- The land use is classified as follows:
- Cultivated areas (**8059.82 ha**);
- Grassland and low shrubland (**12 388.60 ha**);
- Thicket/Dense bush (**206.14 ha**);
- Mine areas (**229.57 ha**);
- Urban Areas (**62.43 ha**); and
- Water bodies (**1 615.96 ha**).

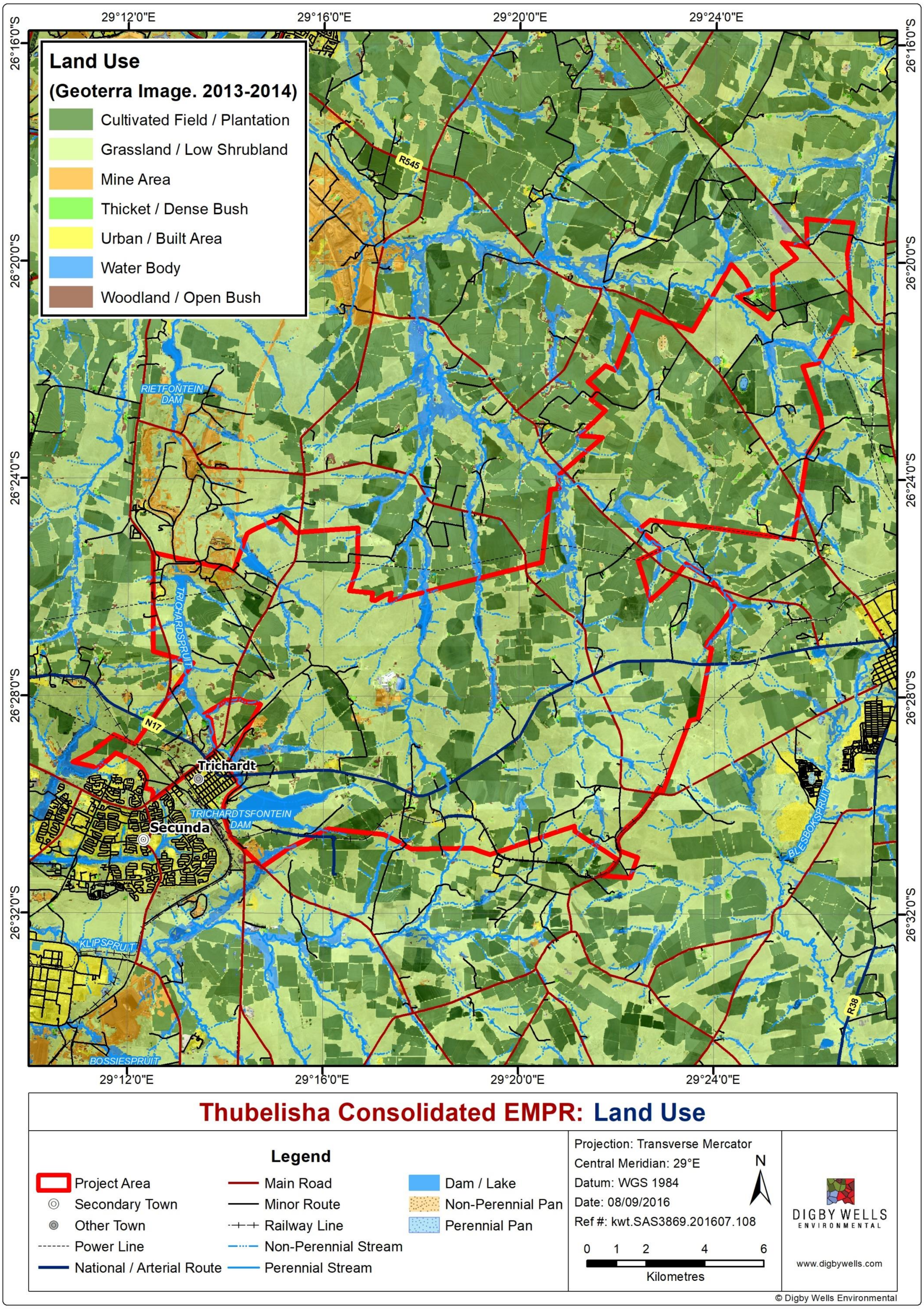

Land Use
(Geoterra Image. 2013-2014)
Cultivated Field / Plantation
Grassland / Low Shrubland
Mine Area
Thicket / Dense Bush
Urban / Built Area
Water Body
Woodland / Open Bush
29°12'0"E
29°16'0"E
29°20'0"E
29°24'0"E
26°16'0"S
26°20'0"S
26°24'0"S
26°28'0"S
26°32'0"S
R545
RIETFONTEIN DAM
TRICHARDSPRUIT
N17
Trichardt
Secunda
TRICHARDTSFONTEIN DAM
KLIPSPRUIT
BOSSIESPRUIT
BLESBOKSPRUIT
R38
Thubelisha Consolidated EMPR: Land Use
Legend
Project Area
Secondary Town
Other Town
Power Line
National / Arterial Route
Main Road
Minor Route
Railway Line
Non-Perennial Stream
Perennial Stream
Dam / Lake
Non-Perennial Pan
Perennial Pan
Projection: Transverse Mercator
Central Meridian: 29°E
Datum: WGS 1984
Date: 08/09/2016
Ref #: kwt.SAS3869.201607.108
N
0 1 2 4 6
Kilometres
DIGBY WELLS ENVIRONMENTAL
www.digbywells.com
© Digby Wells Environmental

Figure 9-3: The Land Use map for the Thubelisha Consolidated EMPr

10 Impact Assessment

10.1 Methodology used in Determining and Ranking the Nature, Significance, Consequence, Extent, Duration and Probability of Potential Environmental Impacts and Risks

Details of the impact assessment methodology used to determine the significance of physical, bio-physical and socio-economic impacts are provided below.

The significance rating process follows the established impact/risk assessment formula:

Significance = Consequence x Probability x Nature

Where

Consequence = Intensity + Extent + Duration

And

Probability = Likelihood of an impact occurring

And

Nature = Positive (+1) or negative (-1) impact

Note: In the formula for calculating consequence, the type of impact is multiplied by +1 for positive impacts and -1 for negative impacts

The matrix calculates the rating out of 147, whereby Intensity, Extent, Duration and Probability are each rated out of seven as indicated in Table 10-3. The weight assigned to the various parameters is then multiplied by +1 for positive and -1 for negative impacts.

Impacts are rated prior to mitigation and again after consideration of the mitigation measure in this EIA/EMP Report. The significance of an impact is then determined and categorised into one of eight categories, as indicated in Table 10-2, which is extracted from Table 10-1. The description of the significance ratings is discussed in Table 10-3.

It is important to note that the pre-mitigation rating takes into consideration the activity as proposed, i.e. there may already be certain types of mitigation measures included in the design (for example due to legal requirements). If the potential impact is still considered too high, additional mitigation measures are proposed.

Table 10-1: Impact Assessment Parameter Ratings

Rating	Intensity/Replicability		Extent	Duration/Reversibility	Probability
	Negative Impacts (Nature = -1)	**Positive Impacts (Nature = +1)**			
7	Irreplaceable loss or damage to biological or physical resources or highly sensitive environments. Irreplaceable damage to highly sensitive cultural/social resources.	Noticeable, on-going natural and / or social benefits which have improved the overall conditions of the baseline.	International The effect will occur across international borders.	Permanent: The impact is irreversible, even with management, and will remain after the life of the project.	Definite: There are sound scientific reasons to expect that the impact will definitely occur. >80% probability.
6	Irreplaceable loss or damage to biological or physical resources or moderate to highly sensitive environments. Irreplaceable damage to cultural/social resources of moderate to highly sensitivity.	Great improvement to the overall conditions of a large percentage of the baseline.	National Will affect the entire country.	Beyond project life: The impact will remain for some time after the life of the project and is potentially irreversible even with management.	Almost certain / Highly probable: It is most likely that the impact will occur. <80% probability.

Rating	Intensity/Replicability		Extent	Duration/Reversibility	Probability
	Negative Impacts (Nature = -1)	Positive Impacts (Nature = +1)			
5	Serious loss and/or damage to physical or biological resources or highly sensitive environments, limiting ecosystem function. Very serious widespread social impacts. Irreparable damage to highly valued items.	On-going and widespread benefits to local communities and natural features of the landscape.	Province/ Region Will affect the entire province or region.	Project Life (>15 years): The impact will cease after the operational life span of the project and can be reversed with sufficient management.	Likely: The impact may occur. <65% probability.
4	Serious loss and/or damage to physical or biological resources or moderately sensitive environments, limiting ecosystem function. On-going serious social issues. Significant damage to structures / items of cultural significance.	Average to intense natural and / or social benefits to some elements of the baseline.	Municipal Area Will affect the whole municipal area.	Long term: 6-15 years and impact can be reversed with management.	Probable: Has occurred here or elsewhere and could therefore occur. <50% probability.

Rating	Intensity/Replicability		Extent	Duration/Reversibility	Probability
	Negative Impacts (Nature = -1)	Positive Impacts (Nature = +1)			
3	Moderate loss and/or damage to biological or physical resources of low to moderately sensitive environments and, limiting ecosystem function. On-going social issues. Damage to items of cultural significance.	Average, on-going positive benefits, not widespread but felt by some elements of the baseline.	Local Local extending only as far as the development site area.	Medium term: 1-5 years and impact can be reversed with minimal management.	Unlikely: Has not happened yet but could happen once in the lifetime of the project, therefore there is a possibility that the impact will occur. <25% probability.
2	Minor loss and/or effects to biological or physical resources or low sensitive environments, not affecting ecosystem functioning. Minor medium-term social impacts on local population. Mostly repairable. Cultural functions and processes not affected.	Low positive impacts experience by a small percentage of the baseline.	Limited Limited to the site and its immediate surroundings.	Short term: Less than 1 year and is reversible.	Rare / improbable: Conceivable, but only in extreme circumstances. The possibility of the impact materialising is very low as a result of design, historic experience or implementation of adequate mitigation measures. <10% probability.

Rating	Intensity/Replicability		Extent	Duration/Reversibility	Probability
	Negative Impacts (Nature = -1)	**Positive Impacts (Nature = +1)**			
1	Minimal to no loss and/or effect to biological or physical resources, not affecting ecosystem functioning. Minimal social impacts, low-level repairable damage to commonplace structures.	Some low-level natural and / or social benefits felt by a very small percentage of the baseline.	Very limited/Isolated Limited to specific isolated parts of the site.	Immediate: Less than 1 month and is completely reversible without management.	Highly unlikely / None: Expected never to happen. <1% probability.

Table 10-2: Probability/Consequence Matrix

Probability	Significance																																					
7	-147	-140	-133	-126	-119	-112	-105	-98	-91	-84	-77	-70	-63	-56	-49	-42	-35	-28	-21	21	28	35	42	49	56	63	70	77	84	91	98	105	112	119	126	133	140	147
6	-126	-120	-114	-108	-102	-96	-90	-84	-78	-72	-66	-60	-54	-48	-42	-36	-30	-24	-18	18	24	30	36	42	48	54	60	66	72	78	84	90	96	102	108	114	120	126
5	-105	-100	-95	-90	-85	-80	-75	-70	-65	-60	-55	-50	-45	-40	-35	-30	-25	-20	-15	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	105
4	-84	-80	-76	-72	-68	-64	-60	-56	-52	-48	-44	-40	-36	-32	-28	-24	-20	-16	-12	12	16	20	24	28	32	36	40	44	48	52	56	60	64	68	72	76	80	84
3	-63	-60	-57	-54	-51	-48	-45	-42	-39	-36	-33	-30	-27	-24	-21	-18	-15	-12	-9	9	12	15	18	21	24	27	30	33	36	39	42	45	48	51	54	57	60	63
2	-42	-40	-38	-36	-34	-32	-30	-28	-26	-24	-22	-20	-18	-16	-14	-12	-10	-8	-6	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42
1	-21	-20	-19	-18	-17	-16	-15	-14	-13	-12	-11	-10	-9	-8	-7	-6	-5	-4	-3	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Consequence	-21	-20	-19	-18	-17	-16	-15	-14	-13	-12	-11	-10	-9	-8	-7	-6	-5	-4	-3	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21

Table 10-3: Significance Rating Description

Score	Description	Rating
109 to 147	A very beneficial impact that may be sufficient by itself to justify implementation of the project. The impact may result in permanent positive change	Major (positive) (+)
73 to 108	A beneficial impact which may help to justify the implementation of the project. These impacts would be considered by society as constituting a major and usually a long-term positive change to the (natural and / or social) environment	Moderate (positive) (+)
36 to 72	A positive impact. These impacts will usually result in positive medium to long-term effect on the natural and / or social environment	Minor (positive) (+)
3 to 35	A small positive impact. The impact will result in medium to short term effects on the natural and / or social environment	Negligible (positive) (+)
-3 to -35	An acceptable negative impact for which mitigation is desirable. The impact by itself is insufficient even in combination with other low impacts to prevent the development being approved. These impacts will result in negative medium to short term effects on the natural and / or social environment	Negligible (negative) (-)
-36 to -72	A minor negative impact requires mitigation. The impact is insufficient by itself to prevent the implementation of the project but which in conjunction with other impacts may prevent its implementation. These impacts will usually result in negative medium to long-term effect on the natural and / or social environment	Minor (negative) (-)
-73 to -108	A moderate negative impact may prevent the implementation of the project. These impacts would be considered as constituting a major and usually a long-term change to the (natural and / or social) environment and result in severe changes.	Moderate (negative) (-)
-109 to -147	A major negative impact may be sufficient by itself to prevent implementation of the project. The impact may result in permanent change. Very often these impacts are immitigable and usually result in very severe effects. The impacts are likely to be irreversible and/or irreplaceable.	Major (negative) (-)

11 Environmental Impact Assessment

The mining method will be by bord-and-pillar with stooping (high extraction) at a depth of 30 – 215 m. Stooping will occur outside of the 1:100 flood lines and developed areas. Subsidence will occur in the areas where bord-and-pillar mining taking place. Access to the underground reserves will be via the TCTS shaft and coal will be brought to the surface by a conveyor via a shaft. The coal brought to the surface will be then transported via an overland conveyor to the existing Twistdraai Export Plant. Two ventilation shafts will be constructed using either raise bore methods so that all spoils fall into mine or blind shaft sinking.

11.1 Proposed Project Interactions with Soils, Land Capability and Land Use

Figure 11-1 indicates the subsidence risk for the delineated soils. Areas of 30 – 50 mining depth will have a definite risk of subsidence. Soils that will be definitely impacted are Avalon, Katspruit, Hutton, Glencore, Mispah and Longlands. Areas of 50 – 100 mining depth will have a high risk of subsidence. Areas of 100 m or more will have a low risk of subsidence. Definite risk of subsidence on soils will be 178.92 ha of land; high risk will be 1 649.83 ha of land and low risk will be 979.34 ha.

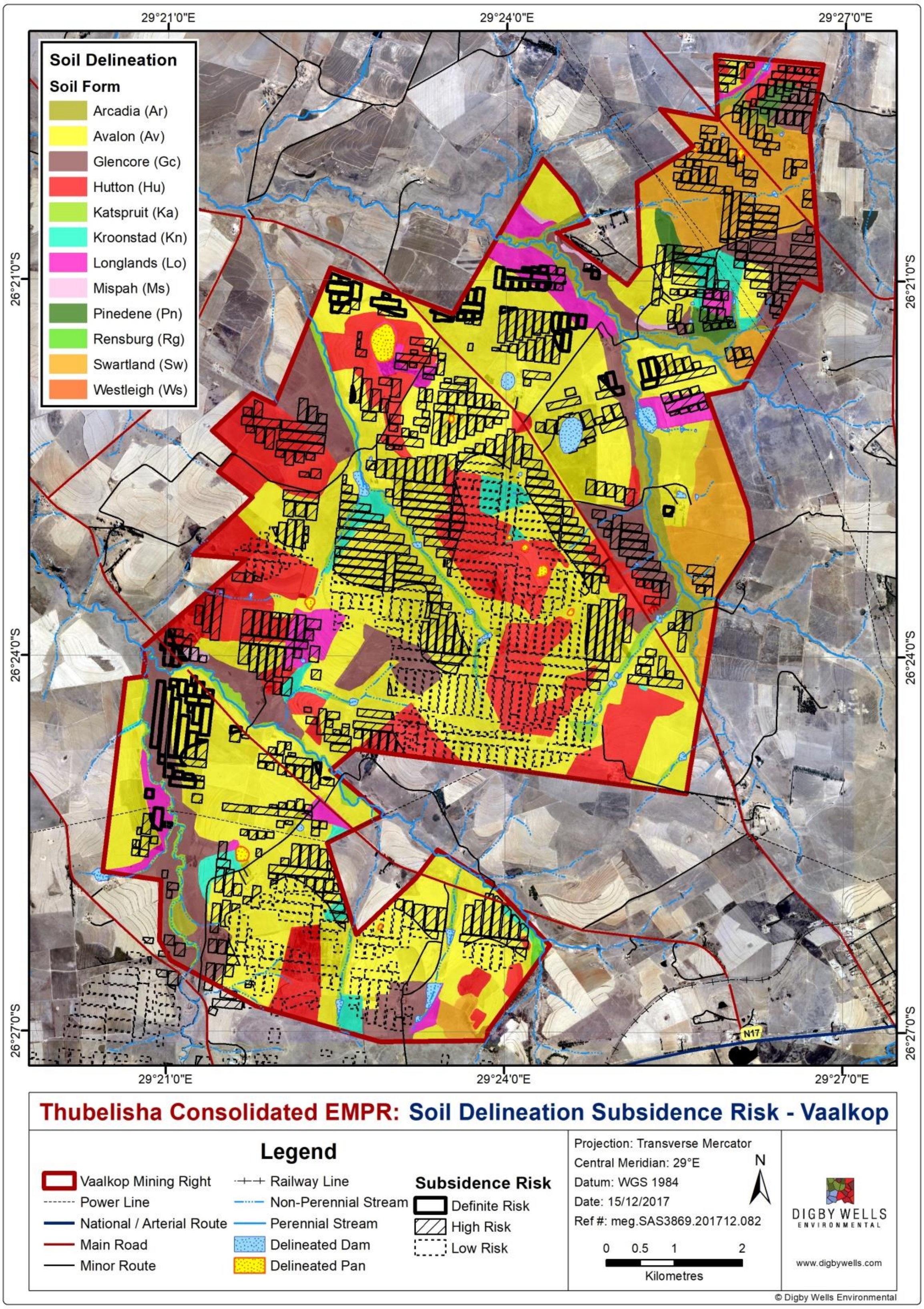


Figure 11-1: Subsidence Risk

11.2 Establishment Phase

The activities that will be undertaken during the construction phase that will impact on the soils and land capability will include:

- Clearing of the footprint area and the construction of ventilation shafts; and
- Clearing and construction of access and service roads.

11.2.1 Soils (Erosion and Compaction)

During the establishment phase site clearing is necessary for the preparation surface infrastructure development (**ventilation shafts, 1.75 ha**) where vegetation will be removed along with topsoil. When soil is removed, the physical properties are changed and the soils' chemical properties will deteriorate unless properly managed. When organic matter has been removed either by the clearing of an area for development or by erosion; the soils' fertility is reduced or soil acidity will be increased.

Vehicles will drive on the soil surface during the establishment phase, thereby causing compaction of the soils. This reduces infiltration rates and ability for plant roots to penetrate the compacted soil.

Soil will be prone to erosion where vegetation has been removed during the establishment phase. The loss of vegetation cover will exacerbate the impact as runoff potential will be increased and increased runoff potential leads to increased erosion hazards. Once the soil is eroded it reduces the overall soil depth and as a result the land capability reduces.

Soils should be handled with care from the establishment phase through to the decommissioning phase.

11.2.2 Land Capability and Land Use

Land capability loss is anticipated to be restricted to the vicinity of the surface infrastructure (ventilation shafts). There is no loss in land capability and land use; as there will be no open pit, waste rock dumps and tailings storage facilities on site.

11.2.3 Management Actions and Targets

Management actions and targets include the following:

- If possible topsoil should be removed when the soil is dry, as to reduce compaction;
- If any erosion occurs, corrective actions must be taken to minimise any further erosion from taking place;
- The soils stripped for the ventilation shafts should be stripped and conserved for rehabilitation;
- Access roads should have the topsoil stripped at 0.3 m and stockpiled for rehabilitation;
- Soil stockpiles should be well managed and protected from erosion, so they are available for use in the rehabilitation process;
- The handling of the stripped topsoil should be minimised to ensure the soil's structure does not deteriorate significantly;
- The stockpiles should be vegetated to reduce the risk of erosion, and to reinstitute the ecological processes within the soil;
- Only the designated access routes are to be used to reduce any unnecessary compaction; and
- Ensure proper storm water management designs are in place.

11.2.4 Impact Ratings

The establishment phase impacts are rated in the Table 11-1.

Table 11-1: Potential Impacts for the Loss of Soils as a Resource: Erosion and Compaction

Dimension	Rating	Motivation	Significance
Site clearing and topsoil removal			
Impact Description: Loss of topsoil as a resource: During clearing of vegetation and removal of soil for establishment of ventilation shafts (1.75 ha), the soil chemical and physical properties are impacted on. The movement of vehicles on the soil surface causes compaction which reduces the vegetation's ability to grow and as a result erosion could occur.			
Prior to Mitigation/Management			
Duration	5	Vegetation and soil will be removed in preparation of shafts, but the impact may be less than 15 years	Minor (-60)
Extent	3	Loss of soil (erosion and compaction) will only occur within project area	

Dimension	Rating	Motivation	Significance
Intensity	4	Vehicles moving on the surface may result in compaction leading to erosion which can be serious but the impact can be reversed.	
Probability	5	By excavating the soil it will certainly impact on the soil and loss of topsoil is certain	
Nature	Negative		
Mitigation/Management Actions			
▪ If possible soil should be removed during dry months, as to reduce compaction ▪ Only clear vegetation when and where necessary; ▪ Only the designated access routes are to be used; ▪ If erosion occurs, corrective actions must be taken to minimise any further erosion from taking place; ▪ Compaction of the removed soil should be avoided by prohibiting traffic on stockpiles; and ▪ Ensure designed storm water management are in place.			
Post-Mitigation			
Duration	2	Loss of soil will be not significant with mitigation measures impact will be less.	
Extent	2	Loss of soil will be local and extend across the project area.	
Intensity	3	Loss of soil can will take place if mitigations measures are not implemented	Negligible (-28)
Probability	4	Losses of soil as a resource will probable occur.	
Nature	Negative		

11.3 Operational Phase

During the operational phase, the following activities are expected to take place that will impact on the soils and land capability:

- Subsidence of the surface after high extraction mining;
- Loading of the coal brought to the surface to the conveyor at the shaft and the conveying of the coal to the processing plant;
- Stockpiling of coal before transporting to plant; and
- Dust suppression along access and conveyer route from the shaft to the bunker.

11.3.1 Soils and Land Capability

Bord and pillar method with high extraction mining can result in subsidence; in areas where the depth of mining is shallow and the roof support is weak. High extraction mining and shallower mining activities will have greater negative impacts as the surface is at great risker from destabilisation, resulting in possible subsidence if mitigation measures are not carried out. The 30-50 m mining depth will have a definite risk of subsidence, 50-100 m mining depth has a high risk of subsidence and 100 or more has a low risk of subsidence.

The following impacts might occur due to high extraction:

- Surface cracking at zones of expansion and contraction
- Subsidence
- Ponding due to changes to topography and surface hydrology

The significance of the impacts on the soils on the site differs according to the soil forms found:

- Free draining red and yellow brown soils; and
- Black and dark brown clay rich soils.

Bord and pillar with high extraction method of mining will have a negative impact on soils especially wetland soils as they will lose a lot of water and potential for collapse of the surface. Underground mine could potentially cause significant surface subsidence. This may significantly restrict post-mining land capability and agricultural productivity, for example if the subsided areas result in ponds/waterlogging conditions, sinkholes and/or cracking of the surface.

11.3.2 Management Actions and Targets

- If any erosion occurs, corrective actions must be taken to minimise any further erosion from taking place;
- Only the designated access routes are to be used to reduce any unnecessary compaction;
- Monitoring of undermined areas to assess the effects of subsidence at the surface
- All soil removed from the trench being excavated must be placed aside and stored so that it will be used later for trench backfilling;
- The handling of the stockpiled topsoil should be minimised to ensure the soil's structure does not deteriorate significantly; and
- The stockpiles should be vegetated to reduce the risk of erosion, and to reinstitute the ecological processes within the soil.

Failing these mitigation measures, the only other alternative will be to compensate the farmers for loss of productive land.

11.3.3 Impact Ratings

The operational impacts described are rate in Table 11-2, Table 11-3 and Table 11-4.

Table 11-2: Potential impacts for the maintenance of roads, topsoil stockpiles and land capability

Dimension	Rating	Motivation	Significance
Activity and Interaction: Maintenance of roads and topsoil stockpiles			
Impact Description: Topsoil losses can occur during the operational phase as a result of rainwater runoff and wind erosion from roads and soil stockpiles where steep slopes are present. Compaction of soils during operational phase will occur.			
Prior to Mitigation/Management			
Duration	5	Roads will be used and soils will be stockpiled during this phase for the length of this operation therefore posing an impact on soils if not mitigated accordingly	Moderate (negative) - 91
Extent	3	Loss of topsoil will only occur within project area	
Intensity	5	Loss of usable topsoil may result in loss of land capability and land use. Soil regeneration takes a very long time.	
Probability	7	Compaction and erosion of soil if mitigations are not implemented will definitely occur	
Nature	Negative		
Mitigation/Management Actions			
▪ Ensure topsoil is stored in one dedicated stockpile, 3 m high and away from drainages lines and surface water; ▪ Only the designated access routes are to be used; ▪ If erosion occurs, corrective actions must be taken to minimise any further erosion from taking place; and ▪ Stockpiles are to be maintained in a fertile and erosion free state by sampling and analysing annually for macro nutrients and soil pH, and vegetating the stockpiles to reduce erosion such as such as *cynodon dactylon, eragrostis tef, eragrostis chloromelas, chloris gayana, digitaria eriantha and panicum*.			
Post-Mitigation			
Duration	4	Roads will be used and soils will be stockpiled during this phase for the length of this operation therefore posing an impact on soils if not mitigated accordingly	Negligible (negative) - 27
Extent	2	With mitigation the impact should be limited to the extent to where the stockpiles will be located.	
Intensity	3	With mitigation this should significantly be reduced.	
Probability	3	With mitigation the likelihood of the impact occurring is limited.	

Dimension	Rating	Motivation	Significance
Nature	Negative		

Table 11-3: Potential impacts of operational phase on soils, land capability and land use (30 – 100 m below ground level)

Dimension	Rating		Significance
Activity and Interaction: Potential surface subsidence from collapsed underground mine roof			
Impact Description: Collapsed underground mine roof could potentially cause significant surface subsidence. This may restrict post mining land capability and agricultural productivity. Surface cracking and subsidence will occur due to large areas that could be affected by the high extraction. Due to this land capability will potentially alter reducing the capability to wilderness.			
Prior to Mitigation/Management			
Duration	7	As a result of the mining method it is expected that the impact would be beyond the project life without mitigation adopted.	Major (-133)
Extent	5	Without mitigation the impact is expected to occur within the region.	
Intensity	7	Serious impacts to the land capability and land use will occur as a result of mining (30-100 m) and adopting no mitigation as a result of potential subsidence.	
Probability	7	The impact on soils will definitely occur.	
Nature	Negative		
Mitigation/Management Actions			
▪ Monitoring of undermined areas to assess the effects of subsidence at surface; and ▪ No mitigation measures will reduce the impact of definite subsidence.			
Post-Mitigation			
Duration	6	With mitigation the duration would be limited to the project life	Moderate (-96)
Extent	4	With mitigation the duration of the impact would be limited to the project area.	
Intensity	6	Even with mitigation being adopted there will be a serious loss of agricultural productivity	
Probability	6	It is expected that the impact is likely to occur.	
Nature	Negative		

Table 11-4: Potential impacts of operational phase on soils, land capability and land use (>100 m below ground level)

Dimension	Rating		Significance
Activity and Interaction: Potential surface subsidence from collapsed underground mine roof			
Impact Description: Collapsed underground mine roof could potentially cause significant surface subsidence. This may restrict post mining land capability and agricultural productivity. Surface cracking and subsidence will occur due to large areas that could be affected by the high extraction.			
Prior to Mitigation/Management			
Duration	7	As a result of the mining method it is expected that the impact would be beyond the project life without mitigation adopted.	Minor (-60)
Extent	4	Without mitigation the impact is expected to occur within the region.	
Intensity	4	Serious impacts to the land capability and land use is expected as a result of mining and adopting no mitigation as a result of potential subsidence.	
Probability	4	The impact is likely to occur and subsidence is a lower risk.	
Nature	Negative		
Mitigation/Management Actions			
▪ Rehabilitation of cracks once identified and areas where vegetation is affected by ponding; ▪ Subsided areas can be backfilled and re-shaped to match the original topography to mitigate ponding and waterlogging conditions depending on the degree of the collapse and available soil material; ▪ Planning for free drainage of ponded areas; and ▪ Monitoring of undermined areas to assess the effects of subsidence at surface			
Post-Mitigation			
Duration	5	With mitigation the duration would be limited to the project life	Negligible (-33)
Extent	3	With mitigation the duration of the impact would be limited to the project area.	
Intensity	3	Even with mitigation being adopted there could still be a serious loss of agricultural productivity	
Probability	3	It is expected that the impact is likely to occur.	
Nature	Negative		

11.4 Rehabilitation and Decommissioning Phase

The major impacts to consider in the decommissioning and rehabilitation of the site will be the loss of topsoil as a resource through erosion and compaction. When the decommissioning and removal of infrastructure takes, vehicles will drive on the surface compacting it and this reduces infiltration rates as well as the ability for plant roots to penetrate the compacted soil. Vegetation cover will be reduced and increases runoff potential, therefore increased runoff potential leads to increased erosion hazards. During the decommissioning and rehabilitation phase, the infrastructure areas will be rehabilitated as per the rehabilitation guideline (See Rehabilitation Report).

11.4.1 Soils

When topsoil is compacted or eroded, the soil profile loses effective rooting depth, water holding capacity and fertility. Movement of vehicles on the soil surface causes compaction, which reduces the vegetation's ability to grow and as a result erosion could be cause. The loss of topsoil as a resource is a serious impact as the natural regeneration of millimetres of topsoil takes hundreds of years.

11.4.2 Land Capability

The infrastructure areas need to be rehabilitated and as a result the impact may be reduced if mitigation measures are implemented. After the infrastructure removal and rehabilitated, the areas must be assessed for compaction and possible erosion risk and corrected immediately. Also subsidence and cracking of soils must be monitored closely.

11.4.3 Management Actions and Targets

The following management actions and targets are provided:

- Implement land rehabilitation measures as defined in rehabilitation report;
- Compacted areas are to be ripped to loosen the soil and vegetation cover re-instated;
- Inventory of hazardous waste materials stored on site should be compiled and arrange complete removal;
- Assess acid generation to predict the acid mine drainage risk;
- Seal the shaft by placing concrete plugs;
- Underground materials should be disconnected prior to removal;
- Ensure proper storm water management designs are in place to ensure no run-off or pooling occurs;
- Conduct soil contamination assessment to assess if any remediation is require prior to future land use development;

- Only designated access routes are to be used to reduce any unnecessary compaction; and
- The topsoil should be shaped taking the pre-mining landscape into consideration.

11.4.4 Impact Ratings

The rehabilitation impacts described are rated in Table 11-5.

Table 11-5: Impact rating during rehabilitation of infrastructure areas and roads

Dimension	Rating	Motivation	Significance
Rehabilitation of infrastructure areas, roads and subsided areas			
Impact Description: Rehabilitation of roads, associated infrastructure and subsided areas (>100 m) could cause compaction and erosion if rehabilitation is not done correctly. This could be as a result of poor vegetation establishment which would result in exposed surfaces and increase the risk of erosion.			
Prior to Mitigation/Management			
Duration	5	The impact on soils would likely to occur if mitigations are not implemented	Minor (negative) - 36
Extent	2	Impact will occur on a limited scale	
Intensity	5	The intensity of the impact is serious and might be irreversible if mitigation measures are not implemented leading to chemical and physical degradation of the soil	
Probability	3	Impact will be unlikely to occur, if mitigation measures are not implemented will lead to compaction, erosion and loss of topsoil	
Nature	Negative		
Mitigation/Management Actions			
▪ Rehabilitate according to the rehabilitation plan; ▪ Return the land conditions capable of supporting prior land use or uses equal or better than prior land use to the extent feasible or practical. ▪ Contour slopes to minimise erosion and run-off; ▪ Plant native vegetation to prevent erosion and encourage self-sustaining development of a productive ecosystem; ▪ Remove buildings to foundation level. All rubble to be relocated to a specified approved rubble dump ▪ Use waste rock for backfill and followed by topsoil to the extent feasible			
Post-Mitigation			
Duration	2	Impact will be less than a year if rehabilitation measures are implemented correctly	Negligible (negative) - 14
Extent	2	Impact will occur on a limited scale	
Intensity	3	The intensity will be reduced if mitigation measures are implemented	

Dimension	Rating	Motivation	Significance
Probability	2	Impact will be unlikely to occur if mitigation measures are implemented	
Nature	Negative		

11.5 Cumulative Impacts

The major impact associated with mining is the disturbance of the natural occurring soil profiles consisting of soil horizons. Rehabilitation of disturbed areas aims to restore land capability. Soil quality deteriorates during stockpiling and replacement of the soil materials into soil profiles during rehabilitation cannot imitate pre-mining soil quality properties. A change in land capability then forces a change in land use. Arable land capability changes to grazing land capability. The impact on post mining land capability could be considered high in the event that mitigation is not adopted for issues related to subsidence which could have impacts to agricultural production on surface.

12 Unplanned Events and Low Risks

There is a risk of accidental spillages of hazardous substances for example hydrocarbons or oils from vehicles or other construction machineries and from waste storage facilities during construction and operational phase.

Contamination is the result of accidental leakage of oils and hydrocarbons from equipment used and it must be ensured that the requirements of the National Environmental Management Waste Act of 2008 are met for prevention of pollution.

12.1 Emergency Procedures

Hydrocarbon spills or leaks are possible to occur; therefore emergency procedures are needed to be put in place for remediation.

- Contractors must ensure that all employees are aware of the procedure for dealing with spills and leaks on site;
- Ensure that emergency spill equipment are available;
- All machines are to be serviced in a correctly concrete area, workshop or at an off-site location;
- If a significant (> 5L) spill occurs is to be cleaned up immediately, reported to the appropriate authorities and recorded; and
- Contaminated soils must be disposed in a registered and licensed Waste Land Facility.

Table 12-1: Unplanned Events, Low Risks and their Management Measures

Unplanned event	Potential impact	Mitigation/Management/Monitoring
Hydrocarbon leaks from vehicles and machinery or hazardous materials	Soil Contamination	▪ Place drip trays where the leak is occurring if vehicles are leaking; and ▪ All vehicles are to be serviced in a correctly concrete area or at an off-site location. ▪ Machines must be parked within hard park areas and must be checked daily for fluid leaks.
Hazardous substance spillage from pipelines or waste storage	Soil Contamination	▪ Prevent any spills from occurring; ▪ If a spill occurs it is to be cleaned up (Drizit spill kit, Oil or Chemical spill kit) immediately and reported to the appropriate authorities; ▪ Pipelines must be checked regularly for leaks; ▪ Pipelines must be maintained; and ▪ Emergency response plans are in place.

13 Soil Management Guidelines

The soil management plan demonstrates how soil should be preserved in a condition as near as possible to its pre-mining state to allow successful rehabilitation. The plan should be implemented during clearance of the soil in preparation for mining activities and includes procedures for storage of soil. This management plan provides the following information:

- A topsoil stripping procedure that aims to maximise volumes of soil removed;
- Stripping soil volumes;
- Monitoring of cracks, subsidence and spillages;
- Stockpile maintenance procedure; and
- A topsoil application procedure to be used during rehabilitation.

13.1 Mitigation and Management

The following management actions and targets are necessary for the mining and infrastructure areas:

- Vegetation clearance and earthworks should be scheduled during the dry months to reduce runoff and water erosion;
- It is recommended that all usable soil I stripped and replaced after final removal of the mining infrastructure;

- Stripped soils should be stockpiled in areas where there is no disturbance or mining development to prevent contamination soils;
- Soil stockpiles need to be vegetated to prevent erosion;
- Ensure all stockpiles have a storm water diversion berm for protection against erosion;
- Only the designated access routes are to be used to reduce any unnecessary compaction;
- Soil compaction can be alleviated by ripping the soils to approximately 0.3 m below ground surface to loosen the soil structure using a ripper and vegetation re-instated;
- Soil stripping and stockpiling should be guided by an environmental officer on site;
- If soils are contaminated they must be stripped and disposed of a licensed waste disposal site; and
- A spill prevention and emergency spill response plan should be compiled and incorporated to the safety protocols.

Soils are most susceptible to compaction when the moisture content is high. The dry winter months (May – October) are thus more suitable for the stripping and replacement of the soils. If soils have to be moved during wet months then special care should be taken to adopt methods that cause minimum compaction.

If possible topsoil should be stripped when the soil is dry, as to reduce compaction.

13.1.1 Supervision and Responsibilities

Close supervision and monitoring of the stripping process is required to ensure that soils are stripped correctly. Monitoring requires assessment of the depth stripped the degree of mixing soil materials and the volumes of material replaced directly or placed on stockpiles. A soil balance sheet needs to be developed to record all soil types and stripping volumes to the stockpiles. This soil balance sheet will aid in the management of the soil stockpiles in addition to keeping record of available soil volumes for rehabilitation.

Table 13-1 below provides roles and responsibilities of the people that will be responsible for implementing soil stripping and stockpiling procedures. The responsibilities of the contractor need to be documented in contract documents.

Table 13-1: Roles and Responsibilities for Soil Stripping and Stockpiling Procedures

Position	Responsibility
Environmental Officer	Ensures that stockpiles inventories are maintained. Monitors stripping and stockpiling process.
Mine Manager	Ensure that the cost associated with clearing and disposal of vegetation and stockpiling is added to the clearing costs.

Contractor	Responsible to undertake the clearing of vegetation, stripping and stockpiling of the soils.

13.2 Summary of Mitigation and Management

Table 13-2 provides a description of the mitigation and management options for the environmental impacts anticipated during the construction, operational and decommissioning and closure phases. Table 13-3 provide a summary of the project activities, environmental aspects and impacts on the receiving environment.

Table 13-2: Soils, Land Capability and Land Use Mitigation and Management Plan

Activities	Phase	Size and scale of disturbance	Mitigation Measures	Compliance with standards	Time period for implementation
Site clearance and topsoil removal	Establishment	Infrastructure footprint	▪ Ensure proper storm water management designs are in place; ▪ If any erosion occurs, corrective actions (erosion berms) must be taken to minimise any further erosion from taking place; ▪ Only the designate access routes are to be used to reduce any unnecessary compaction; ▪ Topsoil should be stripped by means of an truck and shovel and loaded onto dump trucks; ▪ Topsoil stockpiles are to be kept to a maximum height of 3 m and at a slope of 2.5:1; ▪ If possible topsoil should be stripped during dry months, as to reduce compaction; ▪ Compaction of the removed topsoil must be avoided by prohibiting traffic on stockpiles; and ▪ The stockpiles must be vegetated in order to reduce the risk of erosion.	Chamber of Mines Guidelines	Establishment
High extraction mining	Operational	Subsidence	▪ Rehabilitation of cracks once identified and areas where vegetation is affected by ponding; ▪ Planning for free drainage of ponded areas; ▪ Monitoring of undermined areas to assess the effects of subsidence at surface; and ▪ Ensure spill kits are in place and immediately available; and ▪ Only the designate access routes are to be used to reduce any unnecessary compaction.	Chamber of Mines Guidelines	Operational
Demolition of infrastructure and rehabilitation of disturbed areas	Decommissioning & Rehabilitation	Infrastructure footprint	▪ Compacted areas must be ripped to loosen the soil structure; ▪ Implement rehabilitation measures as defined in rehabilitation report; ▪ Topsoil should be replaced for rehabilitation purposes only; and ▪ Stockpiles should be used for their designated final purposes.	Chamber of Mines Guidelines	Decommissioning and Rehabilitation
Post-closure monitoring	Post-closure	Infrastructure footprint and subsidence	▪ The rehabilitated areas must be assessed twice a year for compaction, erosion and fertility; ▪ Compacted areas must be ripped to loosen the soil structure; ▪ Subsidence must be monitored. ▪ Only designated access routes should be used to reduce any unnecessary compaction; and ▪ Corrective actions must be taken to minimise any further erosion from taking place	Chamber of Mines Guidelines	Post-Closure

Table 13-3: Objectives and Outcomes of the EMP

Activities	Potential impacts	Aspects affected	Phase	Mitigation	Standard to be achieved/objective
Site clearance and topsoil removal	Loss of topsoil – erosion, compaction, land capability and land use	Soils	Establishment	▪ Site clearing procedures; ▪ Storm-water management plan	Chamber of mines Guidelines
Construction of infrastructure	Loss of topsoil – erosion, compaction, land capability and land use	Soils	Establishment	▪ Site clearing procedures; ▪ Storm-water management plan	Chamber of mines Guidelines
Establishment of stockpiles	Loss of topsoil – erosion and compaction	Soils	Establishment	▪ Site clearing procedures; ▪ Storm-water management plan	Chamber of mines Guidelines
Maintenance of the stockpiles	Loss of topsoil – erosion and compaction	Soils	Operational	▪ Site clearing procedures; ▪ Storm-water management plan	Chamber of mines Guidelines
High extraction	Loss of land capability – Subsidence and cracking of land	Soils	Operational	▪ Monitoring of cracks and subsidence ▪ Backfilling cracks and reshape	Chamber of mines Guidelines
Demolition of the infrastructure	Loss of topsoil – erosion, compaction, land capability and land use	Soils	Decommissioning	▪ Closure plan	Chamber of mines Guidelines
Rehabilitation of the project area	Loss of topsoil – erosion, compaction and land capability	Soils	Rehabilitation	▪ Rehabilitation plan	Chamber of mines Guidelines
Post-closure monitoring	Loss of topsoil – erosion, fertility and compaction	Soils	Post-closure	▪ Rehabilitation and Closure plan	Chamber of mines Guidelines

13.3 Subsidence, Cracking and Ponding

Cracks, subsidence and ponding need to be rehabilitated in the following manner:

- Areas of ponding, the land will need to be reshaped and rehabilitated to enable free drainage to occur;
- If cracks occurred, topsoil should be cleared around cracks and a mixture of subsoil will be compacted into the crack; and
- Topsoil should be spread over the rehabilitated areas.

Areas where no remedial action is possible, farmers will need to be compensated for the loss of productive land.

13.4 Soil Replacement and Amelioration

All soils should be replaced to a similar depth as was encountered prior to the mining operation. Soils can be replaced to a depth (0.3 m) that will sustain grazing land capability. It is recommended that the soils should be replaced as follows:

- Soil horizons (topsoil and subsoil) should be replaced in the same sequence in which they were stripped;
- The usable subsoil material should be replaced on the reshaped spoil, followed by the topsoil and ensure natural revegetation with the species that were originally in the area;
- Soils should be moved when dry to minimise compaction;
- Compaction should be minimised by use of appropriate equipment and replacing soils;
- Minimise compaction during smoothing of replaced soils by using dozers rather than graders; and
- Following replacement, all soils should be ripped to full rooting depth (0.3 m) using dozer rippers.

Replaced soils require both physical and chemical amelioration as the actions of soil removal, stockpiling and replacement result in high levels of soil compaction and a dilution of the fertility of the soil originally present and concentrated in the surface layers. The following steps should be taken during the amelioration of soils:

- The soils must be ripped to ensure reduced compaction;
- An acceptable seed bed should be produced by surface tillage;
- Restore soil fertility:
  - Soils should be analysed for plant nutrient content;

  - Fertiliser should be applied to raise soil nutrient content to the desired levels; and
  - Fertiliser should be applied annually until the soil fertility cycle is restored at determined rate.

- Incorporate the immobile fertilisers into the plant rooting zone before ripping; and
- Apply maintenance dressing of fertilisers on an annual basis until the soil fertility cycle has been restored.

13.5 Monitoring Plan

Soil monitoring plan guidelines should be put in place to ensure that rehabilitation is a success from a soils perspective. Monitoring should always be carried out at the same time of the year. Soils should be sampled and analysed for the following parameters once in a year:

- pH (KCl);
- Phosphorus (Bray 1);
- Cations: Calcium, Magnesium, Potassium, Sodium (mg/kg);
- Soil organic carbon (%); and
- Soil texture (Clay, Silt and Sand).

The following maintenance is required:

- Repair any damage on soils caused by erosion;
- Monitor subsidence and cracks;
- Demarcate no go zones where possible while the vegetation is establishing;
- The project and rehabbed area must be fenced and animals should be kept off the area until the vegetation is self-sustaining;
- Fertilize rehabbed area with nitrogen containing fertiliser after germination of seeds;
- If soil is contaminated, treat the soils by means of in-situ bio-remediation; and
- If in-situ treatment is not possible then the contaminated soil must be classified according to the Minimum Requirements for the Handling, Classification and Disposal of Hazardous Material and disposed at an appropriate, permitted or licensed disposal facility.

13.6 Soil Compaction

Soil compaction is a major factor limiting post-rehabilitation land capability in the mining industry. All soils should be ripped to full rooting depth (0.3 m) using a dozer rippers to alleviate soil compaction producing soil conditions favourable for re-establishment of vegetation. Deep ripping can free the way for roots to penetrate the soil and access water and nutrients leading to yield increases. Substrates (sewage sludge, pine bark or earthworms) can be also be added to soil to alleviate the severity of soil compaction. Some plant species can be used to penetrate compacted soils since they are more tolerant of high bulk density (Tanner, 2007). Vetiver grass produce dense rooting systems and has ability to penetrate compact soils, therefore it should be planted after soils being ripped.

According to Rethman (2006), soils should be ripped when:

- The moisture content is closer
- to permanent wilting point than field capacity;
- Dry enough to break; and
- Not after significant rainfall.

13.7 Soil Erosion

Soil erosion is known to be a major problem confronting land and resources throughout South Africa (Le Roux *et al*., 2007). Soil erosion on site needs to be prevented during construction, operational and rehabilitation phases. Erosion control measures will need to be implemented in most areas sensitive to erosion. The erosion control measures include the following:

- Drainage controls such as cut-off trenches and culverts must be used to ensure proper management of water runoff to prevent soil erosion and sedimentation;
- Grow Vetiver grass (*Vetiveria zizaniodes)* to form a vegetative barrier and protect the land from surface erosion; and
- Use low wire netting and jute geotextile fences with thick mulch layer to slow and trap water runoff on steep to moderate slopes.

Soil erosion status of the rehabilitated land should be monitored bi-annually and if there is erosion remedial actions should be taken.

14 Conclusions and Recommendations

The area of the study was assessed in terms of the standard soil survey methods (Taxonomic Classification for SA). The major soil forms were Hutton, Avalon. Glencoe, with areas comprising soil forms of Arcadia, Swartland, Rensburg, Bonheim, Kroonstad, Longlands, Katspruit, Pinedene and Mispah. The land capability was dominated by Class II, III and IV. The land use was dominated by cultivated areas (maize and soya beans), livestock farming (grazing) and water bodies (wetlands and rivers).

The fertility status of the soils is generally moderate with some requirement for lime (to counteract acidity) and phosphate fertiliser to achieve full cropping potential. Exchangeable base cations (potassium, calcium, magnesium) are present at sufficient levels and there is neither sodium nor salinity hazard. Texture is variable, from silt loam through silt, clay loam to clay.

During the establishment phase site clearing is necessary for the preparation surface infrastructure development (ventilation shafts) where vegetation will be removed and topsoil. When soil is removed, the physical properties are changed and the soils' chemical properties will deteriorate unless properly managed. Vehicles will drive on the soil surface during the establishment phase, thereby causing compaction of the soils.

Bord and pillar method of mining will definitely cause subsidence which will result in a significant impact to soil. The underground mining activities will cause a significant impact on the land capability of the identified soils causing subsidence and cracks (high extraction). Areas of 30 – 50 mining depth will have a definite risk of subsidence. Areas of 50 – 100 mining depth will have a high risk of subsidence. Areas of 100 m or more will have a low risk of subsidence. Definite risk of subsidence on soils will be 178.92 ha of land; high risk will be 1 649.83 ha of land and low risk will be 979.34 ha.

The following recommendations are made to minimise the impact on the soils:

- If possible topsoil should be stripped when the soil is dry, as to reduce compaction, adhering to clearly defined guidelines for stripping, with topsoil being saved separately.
- The soil stockpile should have a maximum height of 4 m to minimise adverse effects on soil chemical and physical properties.
- Stockpiles should be protected by a berm wall to prevent erosion of stockpiled material and deflect surface water runoff.
- Runoff must be controlled and managed by use of proper storm water management.
- Fuel and oils spills are common, remediate using commercially available emergency clean up kits and focus on awareness of prevention.
- Replaced soils require both physical and chemical amelioration as the actions of the soil removal; stockpiling and replacement result in soil compaction and dilution of the soil fertility. The actions that should be taken during the amelioration of soils include:
  - Soils must be ripped to ensure reduced compaction;
  - Restore soil fertility;
  - Incorporate fertilisers in to the planting zone; and
  - Apply maintenance dressing of fertilisers on an annual basis until the soil fertility cycle has been restored.

15 References

de Villiers, M.C., Nell, J.P., Barnard, R.O. and Henning, A. 2003. Salt-affected soils: South Africa. ISCW Project GW56/003/20. Agricultural Research Council – Institute for Soil, Climate and Water, Pretoria, South Africa.

du Preez, C., Mnkeni, P. and van Huyssteen, C. 2010. Knowledge review on land use and soil organic matter in South Africa. 19th World Congress of Soil Science, Solutions for a Changing World. Brisbane, Australia. p. 41-44.

Fey, M., Hughes, J., Lambrechts, J., Dohse, T., Milewski, A., and Mills, A. 2010. Soils of South Africa. Cape Town, South Africa. Cambridge University Press.

IFC. April, 2007. General Environmental, Health and Safety Guidelines. International Finance Corporation, Washington DC.

IFC. January, 2012. Performance Standards on Environmental and Social Sustainability and Guidance Notes. International Finance Corporation, Washington DC.

Le Roux, J.J., Newby, T.S., and Sumner, P.D. 2007. Monitoring soil erosion in South Africa at a regional scale: review and recommendations. South African Journal of Science, 103 (329-335).

Rethman, N.F.G. 2006. A review of causes, symptoms, prevention and alleviation of soil compaction on mined land. Mined land research, COALTECH 2020.

South African Sugar Association. 1999. Identification and management of the soils of the South African Sugar Industry. Mount Edgecombe, Durban, South Africa.

Soil Classification Working Group. 1991. Soil Classification, A Taxonomic System for South Africa. Soil and Irrigation Research Institute, Department of Agricultural Development, Pretoria.

Tanner, P. 2007. Guidelines for the Rehabilitation of Mined Land. Chamber of Mines South Africa and Coaltech.

Appendix A: CV

Mr Siphamandla Madikizela

Soil Scientist

Terrestrial and Mine Services

Digby Wells Environmental

Education

- 2012 – 2014: MSc in Soil Science – University of KwaZulu-Natal.
- 2011 – 2011: BSc Honours in Soil Science – University of KwaZulu-Natal.
- 2008 – 2010: BSc in Hydrology and Soil Science – University of KwaZulu-Natal.

Employment

- March 2016 – Present: Digby Wells Environmental - Soil Scientist.
- August 2013 – March 2016: EcoPlanet Bamboo (Pty) Ltd - Assistant Plantation Manager.
- 2010 – 2013: University of KwaZulu-Natal - Student demonstrator (2nd and 3rd years majoring in Soil Science).
- 2012: Jeffares & Green Consulting Company - Field Assistant.

Experience

Siphamandla Madikizela is a Soil Scientist and completed his MSc in Soil Science at University of KwaZulu-Natal. Prior to his employment at Digby Wells, Siphamandla worked as an Assistant Plantation Manager for EcoPlanet Bamboo southern Africa. He joined Digby Wells in March 2016 and is part of the Terrestrial and Mine Department. His role involved conducting soil surveys, soil contamination assessment, and identification of soil forms, interpreting results of soil samples, land use and land capability environmental impact assessments and writing detailed scientific reports.

Project Experience

- Scoping and Environmental Impact Reporting for Proposed Palmietkuilen Colliery near Springs – Canyon Resources (Pty) Ltd – Soil Scientist.
- Scoping and Environmental Impact for an Environmental Authorisation Application in support of the Prospecting Right Applications – Anglo American Platinum Ltd – Soil Scientist.
- Scoping and Environmental Impact for Grootvlei TSF Reclamation Project - Ergo Mining (Pty) Ltd – Soil Scientist.
- Risk Assessment and Associated Water Use License Application for the Proposed KPSX Northern Bypass, in Mpumalanga – South32 SA Coal Holdings (Pty) Limited – Soil Scientist.

- Environmental and Social Impact Assessment Update for the Sadiola Sulphides Project (2016), Mali - Société d'Exploitation des Mines d'Or de Sadiola S.A – Soil Scientist.
- Environmental Impact Assessment for the proposed infrastructure expansion at Grootegeluk Coal Mine – Exxaro Reductants (Pty) Ltd – Soil Scientist.
- Gap analysis for the Environmental Authorisation for the Rietspruit Rehabilitation Project – South32 SA Coal Holdings (Pty) Ltd – Soil Scientist.
- Reviewing of the Soils, land capability and land use Environmental Impact Assessment for Hendrina Reserve – Glencore Operations South Africa (Pty) Ltd – Soil Scientist.
- Rehabilitation Guidelines for Sedibelo West – Sedibelo Platinum Mines Limited – Soil Scientist.
- Contamination Assessment for Konskilde Warehouse, Boksburg, Johannesburg, South Africa – EDF Fenice – Soil Scientist.
- Soil and Agricultural Potential Assessment for Training Facility and Firestation Project, Gauteng – Savannah Environmental (Pty) Ltd – Project Manager and Soil Scientist.
- Agricultural Potential Study, Gumu, Kibali, DRC – Randgold Resources – Project Manager and Soil Scientist.
- Basic Assessment for proposed Borrow Pits near Lephalale – Ledjadja Coal (Pty) Ltd – Soil Scientist.
- Klipspruit Environmental Management Programme Consolidation – South 32 SA Coal Holdings (Pty) Ltd – Soil Scientist.
- Extension on Farm Middelbult for the Universal Kangala Coal Mine – Universal Kangala Coal Mine – Soil Scientist.
- Soil, Land Capability and Land Use Assessment for Vaalkop Area, Mpumalanga – Sasol Mining (Pty) Ltd – Soil Scientist.
- Environmental and Social Impact Assessment for Bougouni Lithium Project, Mali – Birimian Gold Limited – Soil Scientist.

Research

- The Use of Hydrogel Application at Planting for *Bambusa Balcooa* Species at different rates – EcoPlanet Bamboo southern Africa – Assistant Plantation Manger.
- The Effect of Herbicide Application on *Bambusa Balcooa* – EcoPlanet Bamboo southern Africa – Assistant Plantation Manager.

- The Effect of Plastic Mulch on Growth and Yield on *Bambusa Balcooa* - EcoPlanet Bamboo southern Africa – Assistant Plantation Manager.
- Effect of Nitro-S fertilizer on growth and yield of *Bambusa Balcooa* and *Oxytenanthera Abyssinica*.

Responsibilities

- Plant management including adaptive fertilizer applications, pest management and irrigation schemes.
- Managing daily operations including the oversight of large staff teams of unskilled and semi-skilled workers, scheduling of operations and maintenance of farm equipment.
- Managing a schedule of community development activities
- Managing weekly activities in the nursery, including staff and overseeing the arrival and transplanting of new plants.
- Tracking and recording productivity data of the general workers and prepare the weekly KPI's for the corporate office.
- Adherence to international certification standards, in particular the Forest Stewardship Council (FSC), through plantation planning and administrative work.

Short Courses

- Certificate of Attendance: Wild Fire Suppression – Proto team (1-2 June 2015, Bathurst, Port Alfred).
- Certificate of Attendance: Basic Labour Relations (2 September 2015, Cape Town).
- Certificate of Attendance: Conflict Management Workshop (26 October 2015, Port Elizabeth).
- Certificate of Completion: Technical Report Writing (21&22 November 2016)
- Current: Project Management

Professional Affiliations

- Soil Science Society of South Africa (SSSA).

Professional Registration

- 2013: Registered as a Candidate Natural Scientist with The South African Council for Natural Scientific Professions. Registration number: 100033/13.