SOIL, AGRICULTURAL POTENTIAL, LAND CAPABILITY AND LAND USE STUDY: IMPACT OF A PROPOSED TAILINGS PIPELINE ON THE FARMS FRISCHGEWAAGD AND MIMOSA, NEAR THE TOWN OF LEDIG, NORTH WEST PROVINCE

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South African Soil Surveyors Organisation (SASSO)
South African Wetland Society (SAWS)

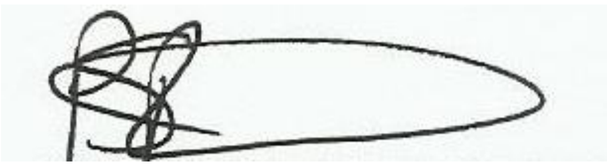
Specialist reports and reports on specialist processes - Checklist		
	NEMA Regs (2014) - Appendix 6	**Reference to section of specialist report or justification for not meeting requirement**
1	A specialist report or a report on a specialised process prepared in terms of these Regulations must contain -	
(a) i	the person who prepared the report; and	Title page
(a) ii	the expertise of that person to carry out the specialist study or specialised process;	Appendix B
(b)	a declaration that the person is independent in a form as may be specified by the competent authority;	Page iii
(c)	an indication of the scope of, and the purpose for which, the report was prepared;	Page 1 - 2
(d)	the date and season of the site investigation and the relevance of the season to the outcome of the assessment;	Page 1
(e)	a description of the methodology adopted in preparing the report or carrying out the specialised process;	Page 5 - 11
(f)	the specific identified sensitivity of the site related to the activity and its associated structures and infrastructure	Page 24 - 32
(g)	an identification of any areas to be avoided, including buffers;	Page 24 and 29
(h)	a map superimposing the activity including the associated structures and infrastructure on the environmental sensitivities of the site including areas to be avoided, including buffers;	Page 4, 23, 25, 27
(i)	a description of any assumptions made and any uncertainties or gaps in knowledge;	Page 1
(j)	a description of the findings and potential implications of such findings on the impact of the proposed activity, including identified alternatives, on the environment;	Page 11 - 40 And Appendix A
(k)	any mitigation measures for inclusion in the EMPr	Page 26 - 32 and Appendix A
(l)	any conditions for inclusion in the environmental authorisation	No additional conditions other than compliance with the mitigation measures provided in this report
(m)	any monitoring requirements for inclusion in the EMPr or environmental authorisation	–Appendix A
(n)	a reasoned opinion -	

.i	as to whether the proposed activity or portions thereof should be authorised and	Page 26 - 41
.ii	if the opinion is that the proposed activity or portions thereof should be authorised, any avoidance, management and mitigation measures that should be included in the EMPr, and where applicable, the closure plan;	The mitigations measures as provided in this report (Page 26 - 32) must be included in the EMPR developed for the project.
(o)	a description of any consultation process that was undertaken during the course of carrying out the study;	No specific consultation was undertaken or deemed necessary as part of this study. Comments received by SLR as part of the EIA were considered in the undertaking of this study.
(p)	a summary and copies if any comments that were received during any consultation process, and -	No specific consultation was undertaken or deemed necessary as part of this study. Comments received by SLR as part of the EIA were considered in the undertaking of this study.
(q)	any other information requested by the competent authority.	None

DECLARATION

I, Petrus Stephanus Rossouw, declare that I –

- act as an independent specialist consultant in the fields of soil science;
- do not have and will not have any financial interest in the undertaking of the activity, other than remuneration for work performed in terms of the Environmental Impact Assessment Regulations, 2014;
- have and will not have any vested interest in the proposed activity proceeding;
- have no, and will not engage in, conflicting interests in the undertaking of the activity;
- undertake to disclose, to the competent authority, any material information that have or may have the potential to influence the decision of the competent authority or the objectivity of any report; and
- will provide the competent authority with access to all information at my disposal regarding the application, whether such information is favourable to the applicant or not.



PETRUS STEPHANUS ROSSOUW

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1. TERMS OF REFERENCE

Rossouw and Associates Soil and Water Science (Pty) Ltd was subcontracted by De Castro and Brits Ecological Consultants CC to conduct a baseline soil, agricultural potential, land capability and land use study as input into an environmental impact assessment document to be compiled by SLR Consulting (Africa) (Pty) Ltd for the footprints of a tailings pipeline. The pipeline is to be constructed on the Farms Frischgewaagd and Mimosa and the intervening area to the north of the Elands River between these farms and is situated close to Ledig, North West Province.

2. INTRODUCTION

Wesizwe Platinum Limited (Wesizwe) is the owner of Bakubung Platinum Mine (BPM), currently shaft sinking on the farm Frischgewaagd 96JQ (Portions 3, 4 and 11). The mine is located near Ledig, just south of the Pilanesberg National Park and Sun City in the North West Province. Two reefs will be mined for Platinum Group Elements - platinum, palladium, rhodium and gold, with copper and nickel as by-products. The project area falls within the Rustenburg and Moses Kotane Local Municipalities of the Bojanala District Municipality. A locality map is provided in Figure 1.

In 2008, Wesizwe conducted an Environmental Impact Assessment (EIA) process for the development of the BPM. The BPM received Environmental Authorisation in 2009, in terms of both the National Environmental Management Act (Act 107 of 1998) (NEMA) and Mineral and Petroleum Resources Development Act (Act 28 of 2002) (MPRDA). A Water Use Licence (WUL) was issued in terms of the National Water Act (Act 36 of 1998) (NWA) in 2010.

While construction at the BPM has commenced, not all facilities have yet been constructed. Mining has not yet commenced. Wesizwe is now proposing to make several changes to the approved mine. The changes are required in order to cater for an increase in ore processing capacity, as well as additional support infrastructure which will require additional Environmental Authorisations, a Waste Management Licence (WML) and additional water uses requiring an amendment to their existing WUL.

Amongst these changes is the proposed construction of an approximately 3.83km long tailings pipeline (including a return water pipe parallel to the tailings pipeline within the same servitude) (hereafter referred to collectively as the tailings pipeline) linking the concentrator plant to the Tailings Storage Facility (TSF). The alignment will be situated on the Farms Frischgewaagd and Mimosa and the intervening area to the north of the Elands River between these farms. The tailings pipeline will be 300mm in diameter and will be raised above ground level on plinths, and the construction servitude will be 30m wide.

This report deals with the potential impact that the tailings pipeline could have on the land use, land capability and agricultural potential of the area during and after construction. The site visit for this study was conducted in summer in November 2015. During December 2015 the layout for the pipeline changed. As the November 2015 site visit entailed an assessment of the soils within a corridor surrounding the original design and the December 2015 pipeline layout falls mostly within this corridor, the findings of the November 2015 site visit are still deemed relevant. Seasonally does not influence soil surveys.

2.1. Aims of the Study

The study aims to:

- Assess the agricultural potential, land capability and land use of the area to be impacted during and after construction of the tailings pipeline;
- Determine the impact that the tailings pipeline might have on the agricultural potential, land capability and land use of the area.
- Propose mitigation measures to negate the potential negative impact of the tailings pipeline on the long term agricultural use of the area.

As part of the EIA that was conducted in 2008, the TSF and plant area were already assessed from a soil perspective. Therefore, these areas have not been re-assessed and only the pipelines between the plant and the TSF form part of this current study.

2.2. Study Area Location

The tailings pipeline stretches from the approximate coordinates 25° 23' 17.61" S and 27° 04' 56.29" E to 25° 23' 55.58" S and 27° 02' 57.63" E. **Figure 1** is a locality map while **Figure 2** is a infrastructure map.

2.3. Study Area Physical Features

The study area is situated approximately 1030 to 1050 m above mean sea level. The area is undulating as can been seen in **Figure 3**.

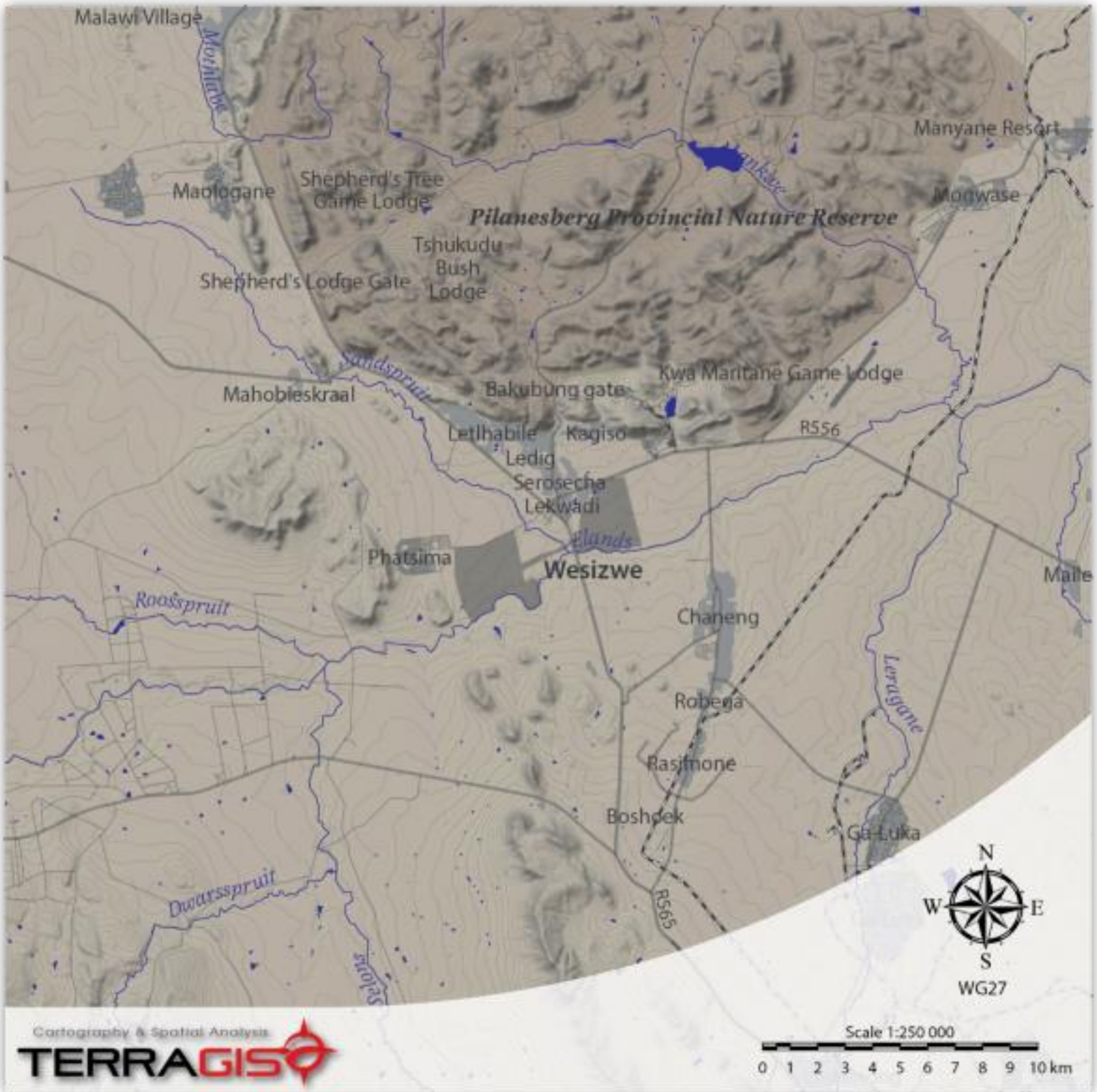

Figure 1 Locality map

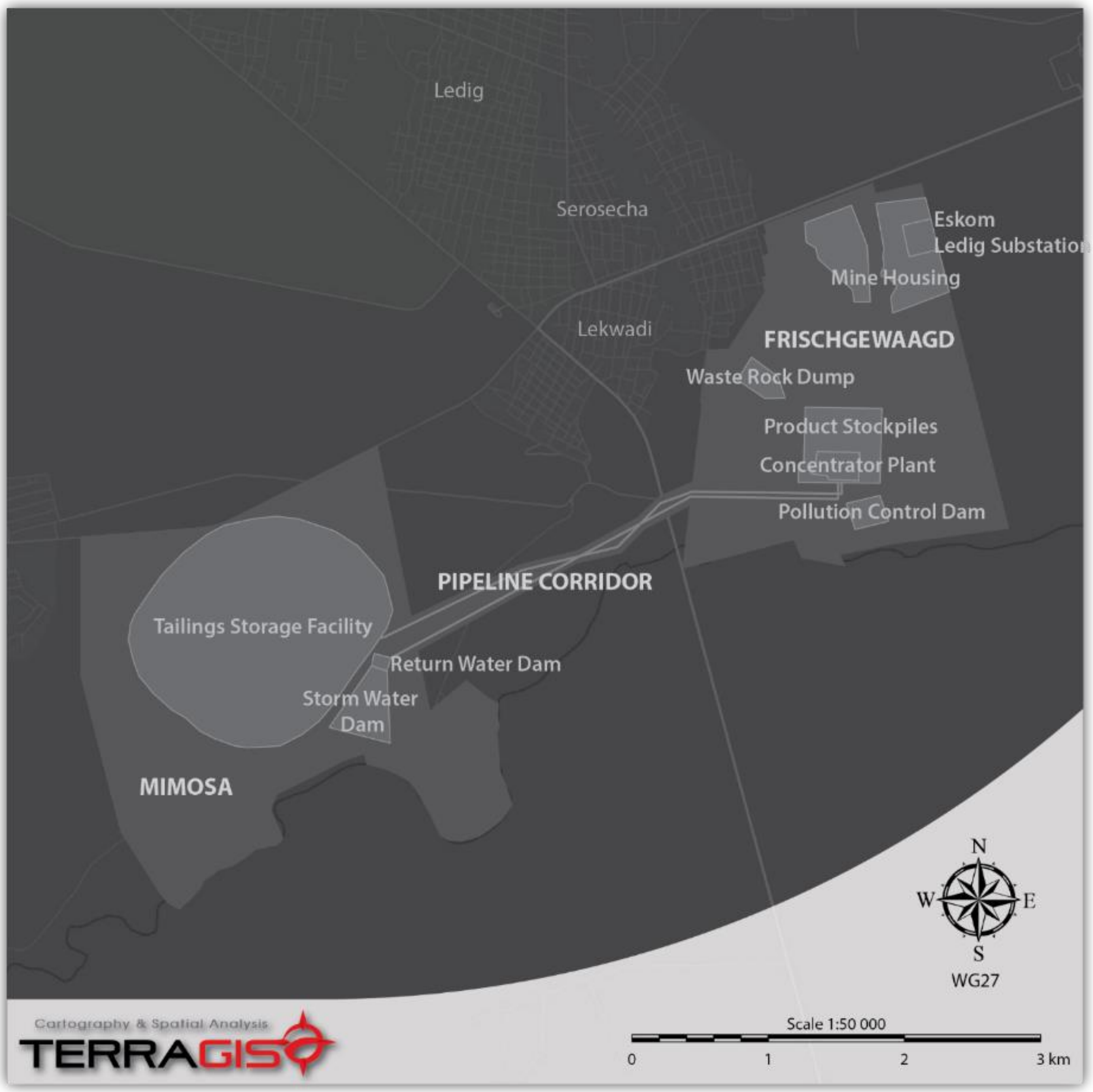

Figure 2 Orientation and infrastructure map

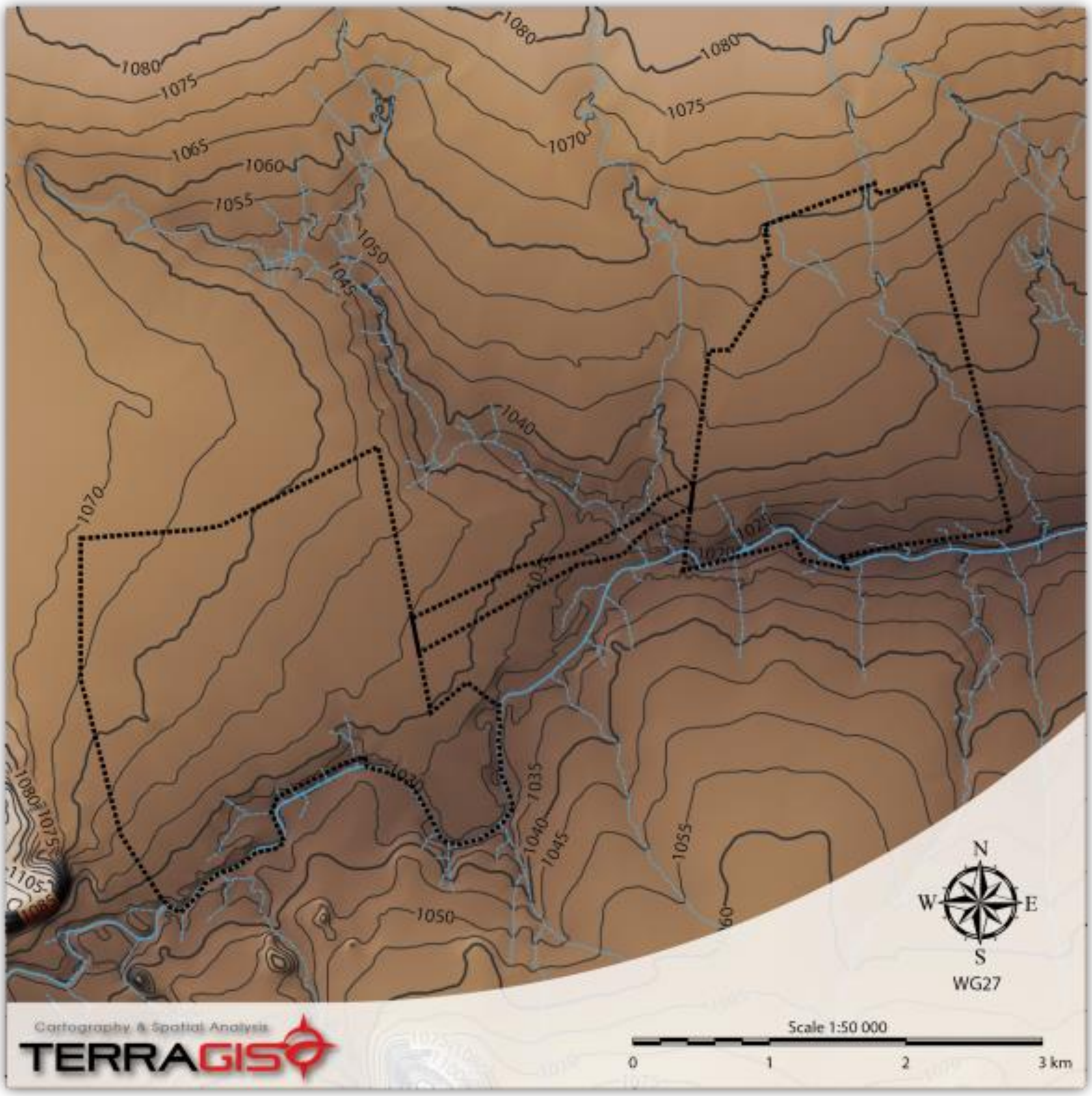

Figure 3 Contour map of the study area and surroundings

3. METHODOLOGY

3.1. Land Type Data

Land type data for the site was obtained from the Institute for Soil Climate and Water (ISCW) of the Agricultural Research Council (ARC) (Land Type Survey Staff, 1972 – 2006). The land type data is presented at a scale of 1:250 000 and entails the division of land into land types, typical terrain cross sections for the land type and the presentation of dominant soil types for each of the identified terrain units (in the cross section). The soil data is classified according to the Binomial System (MacVicar et al., 1977). The soil data was interpreted and re-classified according to the Taxonomic System (MacVicar, C.N. et al. 1991).

3.2. Soil Survey

The study area was traversed and observations regarding the landscape and occurrence of soils were made continuously. Augering was done to a maximum of 1500 mm. In some cases the occurrence of rocks and highly structured soil material hampered deep augering. The soils were classified according to the South African Soil Classification System (MacVicar *et al.,* 1994). Specific emphasis was placed on the identification of the following aspects as these aid in an assessment of the pedohydrology and agricultural potential of the area:

- Fe(II)/Fe(III) layered double hydroxides (manifests as green and blue mottles) that is indicative of moderate conditions of reductions (Eh values of -0.5 to +0.5 V) and usually encountered in wetland soils (temporary and seasonal zones);
- The accumulation of ferrihydrate, lepridocrosite, goethite and hematite in vesicular nodules (red, yellow and brown mottling) owing to the reduction of Fe(III) to Fe(II), under conditions of a fluctuating water table, which leads to the mobilisation of Fe;
- The occurrence of grey colours, especially where mottling is not present, as a further indication of Fe mobilisation and semi-permanent or permanent conditions of water saturation;
- The occurrence of bleached soil horizons that indicate lateral drainage of water;
- The occurrence of gleyed soil horizons that can be indicative of a permanent water table;
- The occurrence of uniform red and yellow colouration that is indicative of well drained areas;
- Signs of Mn mobilisation and/or precipitation as an indication of a fluctuating water table;
- The occurrence of smectite clays that lead to swelling and shrinking characteristics in soil and is conducive to saturated flow in the dry state but not in the wet state;
- Textural changes, and other aspects, in the soil profile that will influence saturated and unsaturated flow of water.
- Occurrence of layers that impede water flow.

Figure 4 shows locations of certain soils that will be discussed in this document.

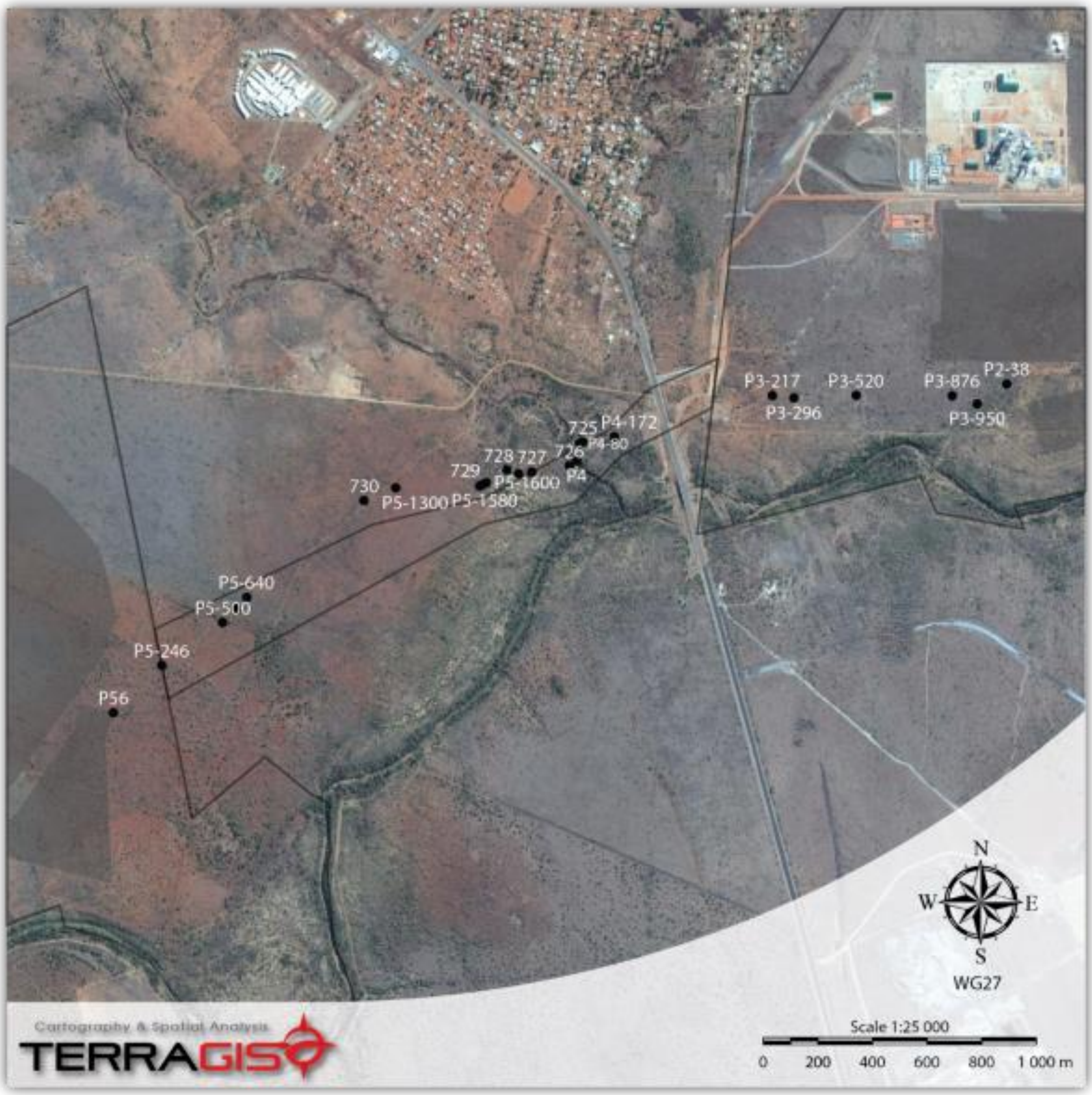

Figure 4 Observation points to be discussed in the report

3.3. Assessing Agricultural Potential

The assessment of agricultural potential rests primarily on the identification of soils that are suited to crop production. In order to qualify as high potential soils they must have the following properties:

- Deep profile (more than 500 mm) for adequate root development,
- Adequate clay content for the storing of sufficient water so that plants can weather short dry spells,
- Adequate structure (loose enough and not dense) that allows for good root development,
- Sufficient clay or organic matter to ensure retention and supply of plant nutrients,
- Limited quantities of rock in the matrix that would otherwise limit tilling options and water holding capacity,

- Adequate distribution of soils and size of high potential soil area to constitute a viable economic management unit, and
- Good enough internal (within the profile) and external (out of the profile) drainage if irrigation practices are considered. Drainage is imperative for the removal (leaching) of salts that accumulate in profiles during irrigation and fertilization. Furthermore, soils that become waterlogged on a regular basis lead to crop stunting, necrosis, yellowing of leaves and low crop yields when cultivated.

Medium and low potential agricultural soils are soils that exhibit, to various degrees, some of the abovementioned characteristics. Not all of the listed characteristics have the same weight when predicting the agricultural potential of a soil. For instance, soil depth is a less important criteria than internal drainage etc.

In addition to pedological characteristics, climatic and soil chemical characteristics are important factors when determining the agriculture potential of a site. The latter mainly entails the determination of any factors that may inhibit plant growth. Saline and other forms of soil pollution, such as heavy metal contamination and acid/neutral/alkaline mine drainage, can adversely affect the production potential of the area. In the case of the study area, sodic soils (identified in areas of salt precipitation on the soil surface and ped surfaces) or soil pollution emanating from tailings and waste dumps, pipelines, pollution control dams etc. were not encountered and soil samples were therefore not collected for chemical analyses. Low soil fertility levels are easily rectified using a number of soil ameliorants.

3.4. Assessing Land Capability Classes

Land capability classes were determined using the guidelines outlined in Section 7 of The Chamber of Mines Handbook of Guidelines for Environmental Protection (Volume 3, 1981). The Chamber of Mines pre-mining land capability system was utilised, given that this is the dominant capability class classification system available in South Africa. The following land capability classes are identified:

- Wetland:
    - Land with organic soils; or
    - A horizon that is gleyed throughout more than 50% of its volume and is significantly thick, occurring within 750 mm of the surface.
- Arable Land:
    - Land, which does not qualify as a wetland;
    - The soil is readily permeable to the roots of common cultivated plants to a depth of 750 mm;
    - The soil has a pH value of between 4,0 and 8.4;
    - The soil has a low salinity and Sodium Adsorption Ratio (SAR);
    - The soil has a permeability of at least 1,5 mm per hour in the upper 500 mm of soil;
    - The soil has less than 10% (by volume) rocks or pedocrete fragments larger than 100mm in diameter in the upper 750 mm;

    - Has a slope (in %) and erodibility factor (K) such that their product is <2.0; and
    - Occurs under a climatic regime, which facilitates crop yields that are at least equal to the current national average for these crops, or is currently being irrigated successfully.
- Grazing land:
    - Land, which does not qualify as wetland or arable land;
    - Has soil, or soil-like material, permeable to roots of native plants, that is more than 250 mm thick and contains less than 50% by volume of rocks or pedocrete fragments larger than 100 mm; and
    - Supports, or is capable of supporting, a stand of native or introduced grass species, or other forage plants, utilizable by domesticated livestock or game animals on a commercial basis.
- Wilderness land:
    - Land, which does not qualify as wetland, arable land or grazing land.

The criteria stipulated for the Wetland land capability class is overridden by the criteria stipulated in the Wetland Delineation Guidelines (Department of Water Affairs and Forestry, 2005) as this is a) a more recent publication and b) based on a better understanding of wetland processes.

The criteria stipulated for soil depth under the Arable land capability class is ignored as crops can be successfully cultivated in soil much shallower than 750 mm. The criteria regarding soil depth as stipulated under section 3.3. (Assessing Agricultural Potential) is used when assigning land capability classes to the soils of the area.

3.5. Assessing Irrigation Classes

To assess the irrigation potential of the soils of the area, the Food and Agriculture Organisation’s (FAO) irrigation classification system is used. The FAO classifies soils into the following five classes in terms of irrigation potential:

- Class 1. Highly suitable for irrigation, few or no limitations and preconditions. Topography is flat, soils are well drained, of moderate permeability and deep, medium textured with a high water holding capacity.
- Class 2. Suitable for irrigation with slight limitations (such as undulating topography), moderately well drained, moderately slow or moderately rapid permeability or moderate depth of soil.
- Class 3. Low suitability with moderately severe limitations, imperfect or somewhat excessively drained soils, slow or rapid permeability or shallow soils.
- Class 4. Not suitable for irrigation under most conditions with severe limitations.

- Class 5. Soils with severe limitations, not recommended at all, such as soils in natural water ways, river plains, soils presently eroded or soils showing signs of a permanent or potential water table.

3.6. Rainfall Data

Rainfall data was obtained from the Institute of Soil, Water and Climate (ARC). The area falls into the 501 to 600 mm rainfall region which is adequate for the dry-land production of most crops, especially citrus, tobacco, sunflower, millet, manna, soya, maize and wheat. Irrigation may be necessary for broad leafed vegetable crops.

3.7. Logic behind Sensitivity Classes and Impact Tables

The following areas are regarded as being of the listed sensitivity class:

- High: wetland and drainage systems, high arable land;
- Medium to high: medium to high potential arable land;
- Medium: medium potential arable land and high potential grazing land;
- Low to medium: medium potential grazing land;
- Low: low potential grazing land.

The proposed method for the assessment of environmental issues is set out in **Table 1**. This assessment methodology enables the assessment of environmental issues including: cumulative impacts, the severity of impacts (including the nature of impacts and the degree to which impacts may cause irreplaceable loss of resources), the extent of the impacts, the duration and reversibility of impacts, the probability of the impact occurring, and the degree to which the impacts can be mitigated.

Table 1 Criteria for assessing impacts

Note: Part A provides the definition for determining impact consequence (combining severity, spatial scale and duration) and impact significance (the overall rating of the impact). Impact consequence and significance are determined from Part B and C. The interpretation of the impact significance is given in Part D.

PART A: DEFINITION AND CRITERIA*		
Definition of SIGNIFICANCE		**Significance = consequence x probability**
Definition of CONSEQUENCE		**Consequence is a function of severity, spatial extent and duration**
Criteria for ranking of the SEVERITY of environmental impacts	**H**	Substantial deterioration (death, illness or injury). Recommended level will often be violated. Vigorous community action.
	M	Moderate/ measurable deterioration (discomfort). Recommended level will occasionally be violated. Widespread complaints.
	L	Minor deterioration (nuisance or minor deterioration). Change not measurable/ will remain in the current range. Recommended level will never be violated. Sporadic complaints.
	L+	Minor improvement. Change not measurable/ will remain in the current range. Recommended level will never be violated. Sporadic complaints.
	M+	Moderate improvement. Will be within or better than the recommended level. No observed reaction.

	H+	Substantial improvement. Will be within or better than the recommended level. Favourable publicity.
Criteria for ranking the DURATION of impacts	**L**	Quickly reversible. Less than the project life. Short term
	M	Reversible over time. Life of the project. Medium term
	H	Permanent. Beyond closure. Long term.
Criteria for ranking the SPATIAL SCALE of impacts	**L**	Localised - Within the site boundary.
	M	Fairly widespread – Beyond the site boundary. Local
	H	Widespread – Far beyond site boundary. Regional/ national

PART B: DETERMINING CONSEQUENCE					
SEVERITY = L					
DURATION	Long term	**H**	**Medium**	**Medium**	**Medium**
	Medium term	**M**	**Low**	**Low**	**Medium**
	Short term	**L**	**Low**	**Low**	**Medium**
SEVERITY = M					
DURATION	Long term	**H**	**Medium**	**High**	**High**
	Medium term	**M**	**Medium**	**Medium**	**High**
	Short term	**L**	**Low**	**Medium**	**Medium**
SEVERITY = H					
DURATION	Long term	**H**	**High**	**High**	**High**
	Medium term	**M**	**Medium**	**Medium**	**High**
	Short term	**L**	**Medium**	**Medium**	**High**
			L	**M**	**H**
			Localised Within site boundary Site	Fairly widespread Beyond site boundary Local	Widespread Far beyond site boundary Regional/ national
			SPATIAL SCALE		
PART C: DETERMINING SIGNIFICANCE					
PROBABILITY (of exposure to impacts)	Definite/ Continuous	**H**	**Medium**	**Medium**	**High**
	Possible/ frequent	**M**	**Medium**	**Medium**	**High**
	Unlikely/ seldom	**L**	**Low**	**Low**	**Medium**
			L	**M**	**H**
			CONSEQUENCE		

PART D: INTERPRETATION OF SIGNIFICANCE	
Significance	**Decision guideline**
High	It would influence the decision regardless of any possible mitigation.
Medium	It should have an influence on the decision unless it is mitigated.
Low	It will not have an influence on the decision.

4. RESULTS AND DISCUSSION

4.1. Land Type Data

The area falls within the Ae64 land type (**Figure 5**). The Ae64 land type is characterised by yellow and red soils with a high base status, but without shallow water tables (within 150 cm of the soil surface). Red structured and apedal soils of high agricultural potential dominate the crest and mid-slope regions of these areas. Structured, black coloured soils with vertic characteristics can occur in the mid-slope regions and especially in the valley bottoms. This land type is usually indicative of a high agricultural potential area.

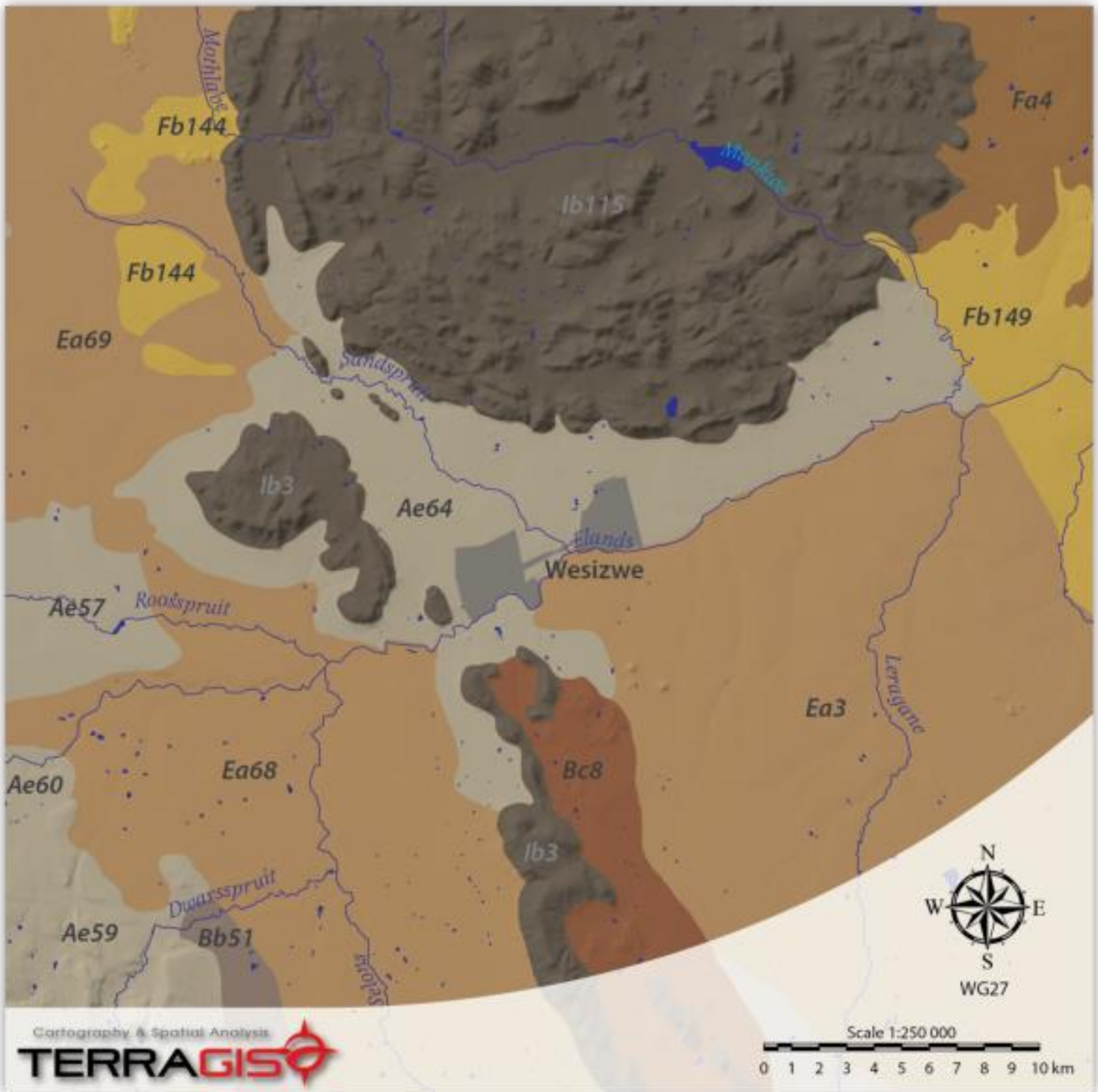

Figure 5 Land type data for the study area

4.2. Soil Survey Data

The following soil forms were identified during the site visit:

- The Valsrivier soil form comprises an orthic A-horizon which overlies a pedocutanic B-horizon and unconsolidated material without signs of wetness. The pedocutanic B-horizon has well developed angular or sub-angular structure with cutanic characteristics (**Figure 6**). Clay illuviation is common in these soils as is the presence of preferential water flow channels. These soils exhibit a sandy clay texture and is in many cases deeper than 150 cm. Calcium-magnesium carbonates nodules are present in the pedocutanic B-horizon and indicates a soil with neutral to slightly alkaline pH conditions. The calcium-magnesium carbonates nodules, in this case, is not a function of soil wetness (regular periods of inundation) but rather an indication of the parent material of the soils being of a basic igneous rock type. The unconsolidated material without signs of wetness (**Figure 7**) that underlies this soil form is of a sandy loam texture and show an apedal structure.

Stones and rock are encountered throughout the profile of the Valsrivier soils in the vicinity of points P2-38. **Figure 8** shows the occurrence of rock and stones on the soil surface of many of these soils in the vicinity of P2-38.

At point P3-876, alluvial material has been washed over a soil of the Valsrivier soil form. The A-horizon, at this point, shows stratification and a sandy texture. The sandy material has been washed into the underlying pedocutanic B-horizon (**Figure 9**) owing to the swelling and shrinking capacity of the smectite clays in this profile.

The pedocutanic B-horizon, in most soils encountered in the vicinity of points P2-38 and P3-876, has characteristics of a vertic A-horizon and may, in fact, be a vertic A-horizon that has been buried by colluvial or alluvial material. The overlying material has, however, undergone pedogenesis to such an extent that it must be regarded as an A-horizon. The South African Soil Classification System does not allow for the classification of a vertic B-horizon and one is therefore necessitated to rather classify these vertic B-horizons as pedocutanic B-horizons. The characteristics of the vertic A-horizon is described under the section dealing with the Arcadia soil form.

The pedocutanic B-horizons encountered in the soil in the vicinity of point P4-172 and P4, which is adjacent a watercourse and probably forms part of a paleo-floodplain, do not show the same vertic horizon characteristics as those encountered towards the east of the study area. These horizons are blocky in structure, show pronounced clay illuviation and are archetypical pedocutanic B-horizons.

Figure 6 Blocky structure and clay illuviation in the pedocutanic B-horizon of the Valsrivier soil form

Figure 7 Unspecified material without signs of wetness underlies the Valsrivier soil form

Figure 8 Rockiness on the soil surface of the soils of the Valsrivier soil form which are encountered towards the eastern section of the pipeline

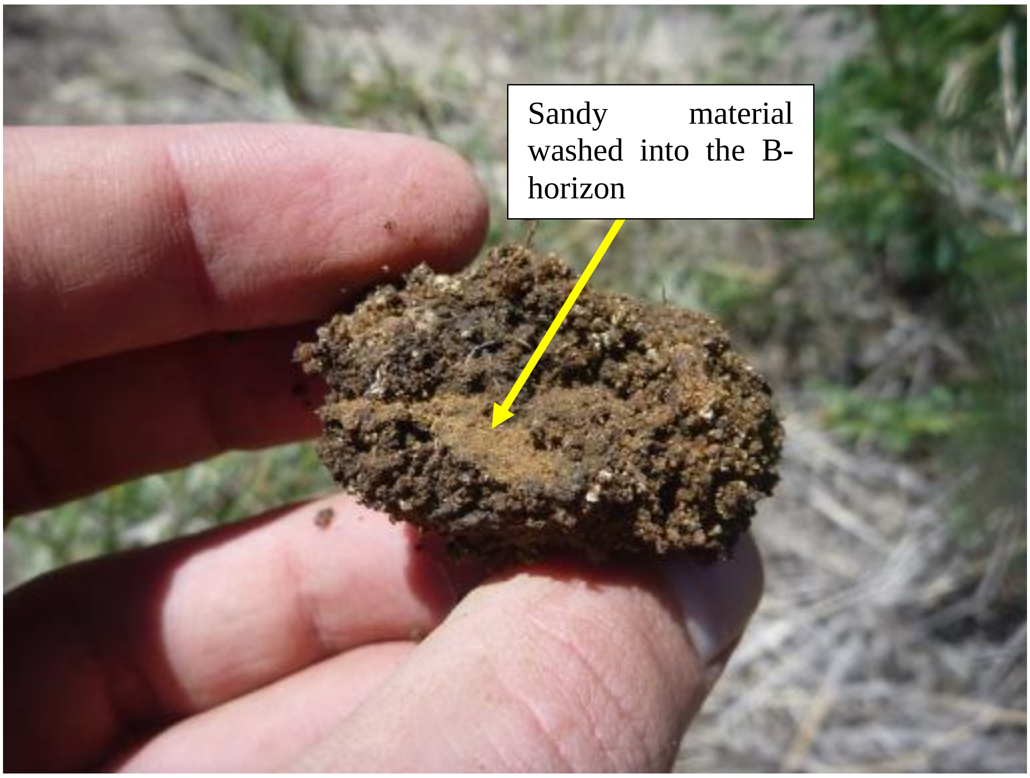

Figure 9 Sandy material has been washed into the pedocutanic B-horizon owing to regular surface flooding at point P3-876

- The Arcadia soil form comprises a vertic A-horizon that overlies unspecified material. The vertic A-horizon has a strongly developed structure and exhibits clearly visible, regularly occurring slickensides in some part of the horizon or in the transition to an underlying layer. The horizon has a high clay content, is dominated by smectite clay minerals and possesses the capacity to swell and shrink markedly in response to moisture changes. Swell-shrink potential is manifested typically by the formation of conspicuous vertical cracks in the dry state (**Figure 10**) and the presence, at some depth, of slickensides (polished or grooved glide planes produced by internal movement) and pressure faces (**Figure 11**). Soil depth ranges from 15 to 120 cm. These soils contain calcium-magnesium carbonates nodules. The unspecified material that underlies this soil form comprise weathering rock (a non-diagnostic lithocutanic B-horizon) as illustrated by **Figure 12**.

Figure 10 Swell-shrink potential is manifested typically by the formation of conspicuous vertical cracks in the dry state

Figure 11 Dark colouration and pressure faces in the Vertic A-horizon

Figure 12 Calcification and weathering of rock in the non-diagnostic lithocutanic B-horizon that underlies the Arcadia soil form

- The Glenrosa soil form comprises an orthic A-horizon overlying a lithocutanic B-horizon. The lithocutanic B-horizon is a pedologically young horizon where clay illuviation has occurred. Soil depth ranges from 10 to 50 cm. These soils are encountered in the vicinity of rock outcrops. **Figure 13** shows a typical area where these soils are encountered.

- The Mispah soil form comprises an orthic A-horizon on hard rock and is associated with the Glenrosa soil form and outcrops. Areas where Glenrosa and Mispah soils abound are points 726 and 727, P3-296 and P3-520. These soils are less than 30 cm deep.

Figure 13 An example of an area where the Glenrosa soil form is encountered (point P3-296)

- The <u>Sepane soil form</u> comprises an orthic A-horizon which overlies a pedocutanic B-horizon and unconsolidated material with signs of wetness. The A- and B-horizons differ markedly in terms of texture and structure with the former being apedal and sandy while the latter is highly structured and sandy clay in texture. **Figure 14** illustrates the difference between these horizons. Manganese mottling and concretions are encountered at the transition of B- and C-horizons as illustrated by **Figure 15**. Soil depth is approximately 50cm.

  Figure 16 also shows the signs of wetness encountered at the transition of the pedocutanic B-horizon to the non-diagnostic lithocutanic B-horizon. Signs of wetness in soil classification does not relate to the presence of water or soil moisture at the time of sampling, but rather to the soil morphological changes brought about by prolonged periods of inundation. Soils that are saturated with water for prolonged periods become reduced and this leads to the breakdowns of Mn(IV) and Fe(III) mineral phases. During this breakdown, Mn^{4+} and Fe^{3+} is reduced to Mn^{3+}, Mn^{2+} and Fe^{2+}. The lower valence state species become soluble and are transported along an oxidation gradient towards pockets of aeration (that formed owing to non-uniform wetting of the soil profile). Oxidation of the lower valence state Mn and Fe ions occur at these pockets of aeration and the precipitation of Mn(IV) and Fe(III) mineral phases occur. This process leads to significant changes in soil morphological features, i.e. grey colouration and/or gleyeing are noted where Mn and Fe have been removed from the soil matrix and yellow, red, brown, black, blue and green mottling occur at the points of Mn and Fe accumulation.

These soils are encountered in a drainage line at point P3-217. The soils are bordered by soils of the Glenrosa soil form. **Figure 17** illustrates the heterogeneity of this area in terms of soil form distribution.

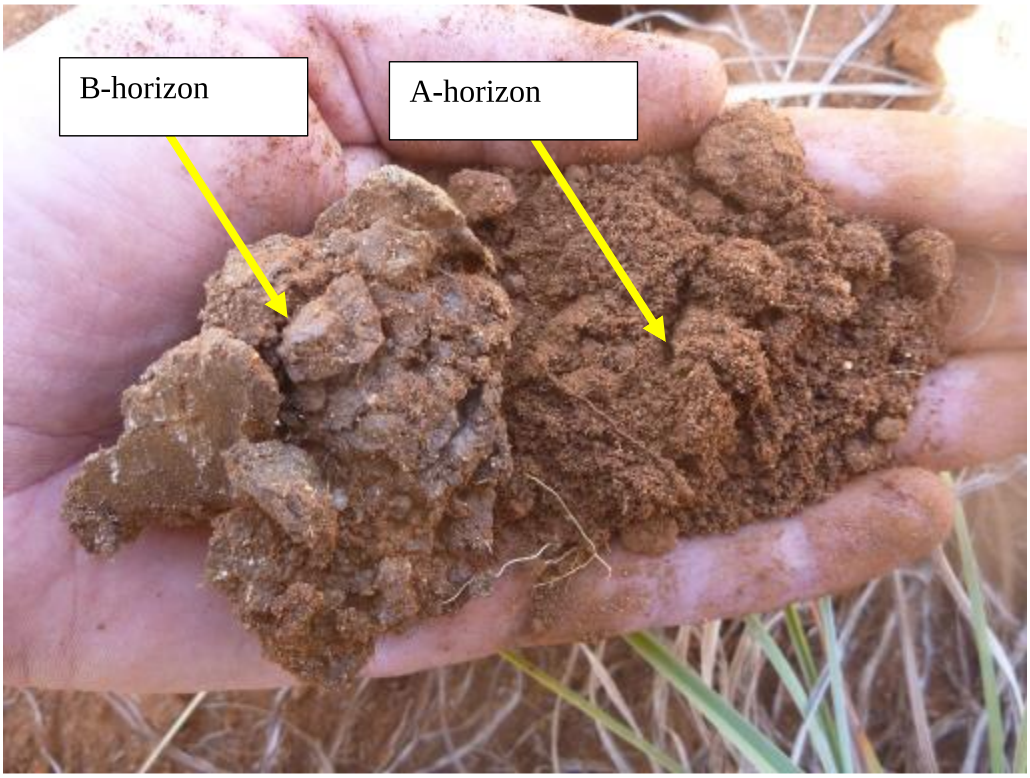

Figure 14 The A- and B-horizons differ markedly in the Sepane soil form in terms of texture and structure

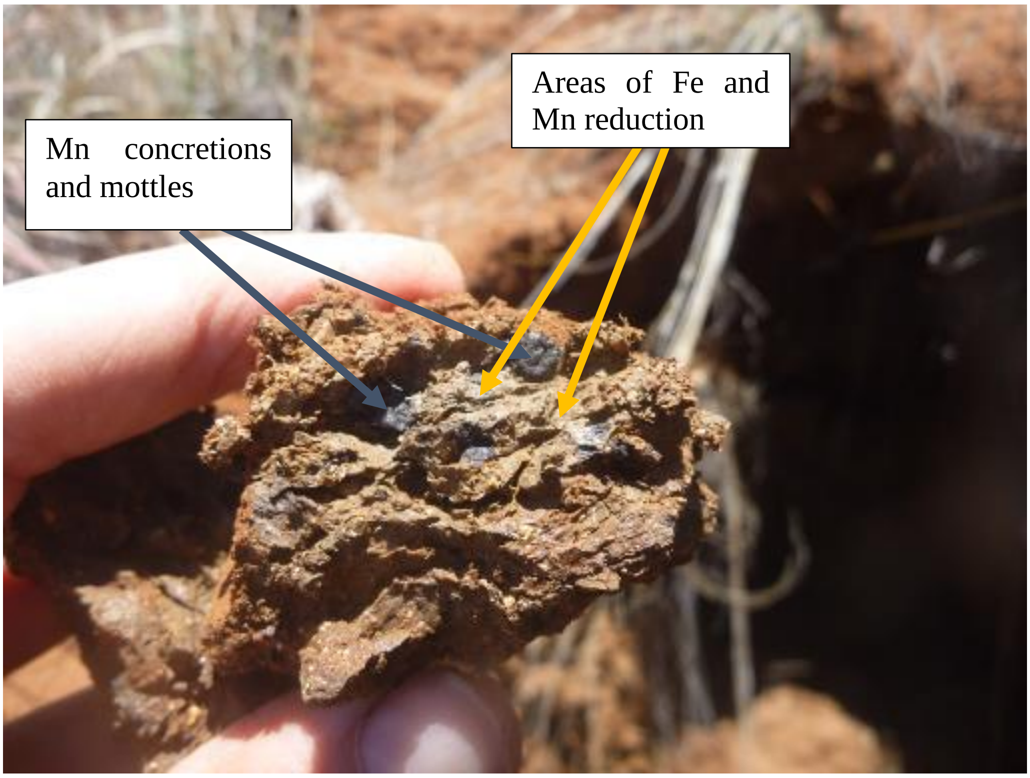

Figure 15 Signs of wetness in the Sepane soil form

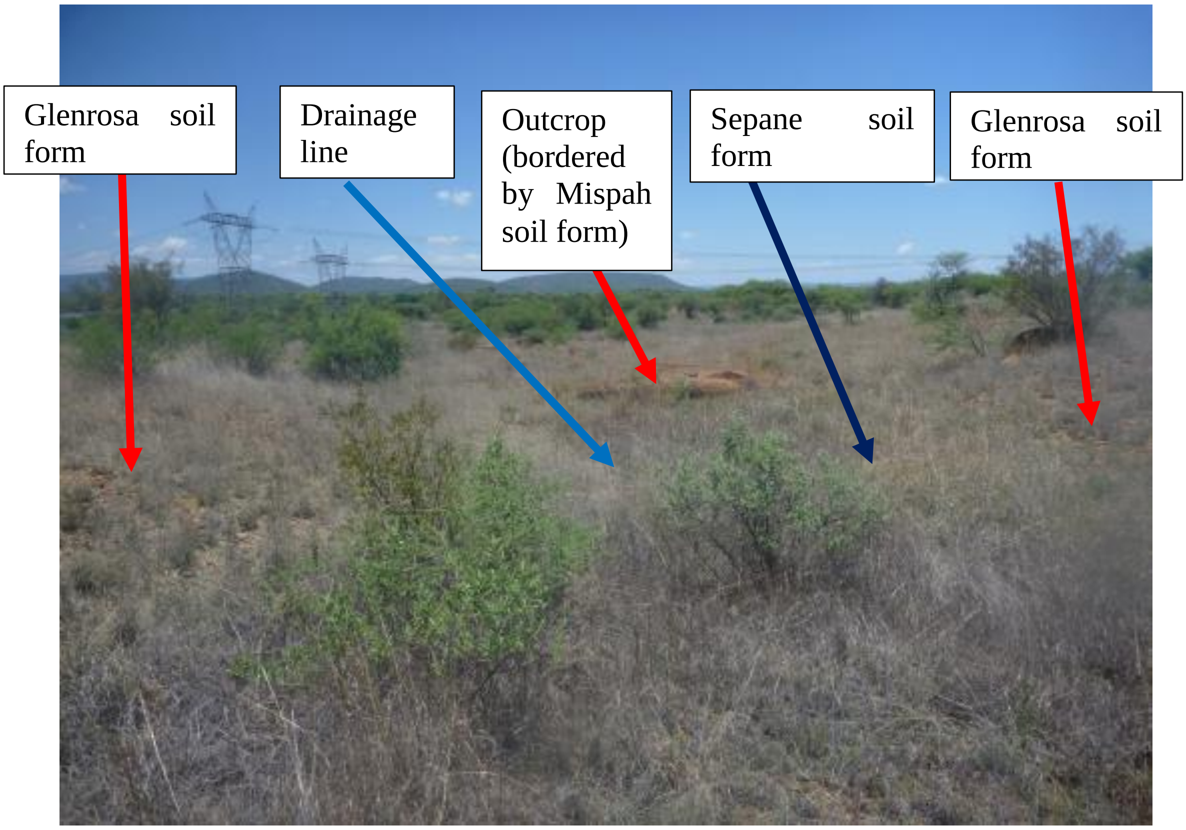

Figure 16 Soil distribution in the drainage line at point P3-217

- The Oakleaf soil form comprises an orthic A-horizon that overlies a neocutanic B-horizon and unspecified material. The neocutanic B-horizon is characterised by colour variation due to clay movement and accumulation and exhibits an apedal or weakly developed structure. The Oakleaf soil form is encountered in the drainage line at point P4. This soil was originally characterised by stratified alluvium (Dundee soil form), but the degree of pedogenesis it has undergone resulted in a soil in which almost all signs of stratification have disappeared. The soil borders a soil of the Valsrivier soil form as illustrated by **Figure 17**. **Figure 18** is a photo of the area. **Figure 19** shows the colour variation in the neocutanic horizon. This soil is approximately 120 cm deep.

- The Shortlands soil form comprises an orthic A-horizon that overlies a red structured B-horizon. The red structured B-horizon exhibits a uniform red colour that is not directly inherited from the rock, but is the result of the relative accumulation of iron oxides following mineral weathering. The horizon has strong rather than moderate blocky structure in the dry state. Pedality in the B-horizon is the result of a sufficient amount of clay and the presence of 2:1 layered clay minerals. The red structured B-horizon usually develops residually from the parent rock; less commonly is it developed in colluvium and rarely in alluvium material. The iron oxides which coat the mineral particles in these soils, coupled with a high-ish clay content, tend to counteract eluviation of clay, although red structured B horizons invariably contain reddish coloured clay-skins. The red structured B-horizon is underlain by saprolitic material that shows no signs of wetness. These soils are therefore well-drained, oxidising environments were water ponding, at any depth, is not expected to occur on a regular basis. The soils are deeper than 1200 mm in most cases, although rocky soils do occur. **Figure 19** illustrates the red structured B-horizon.

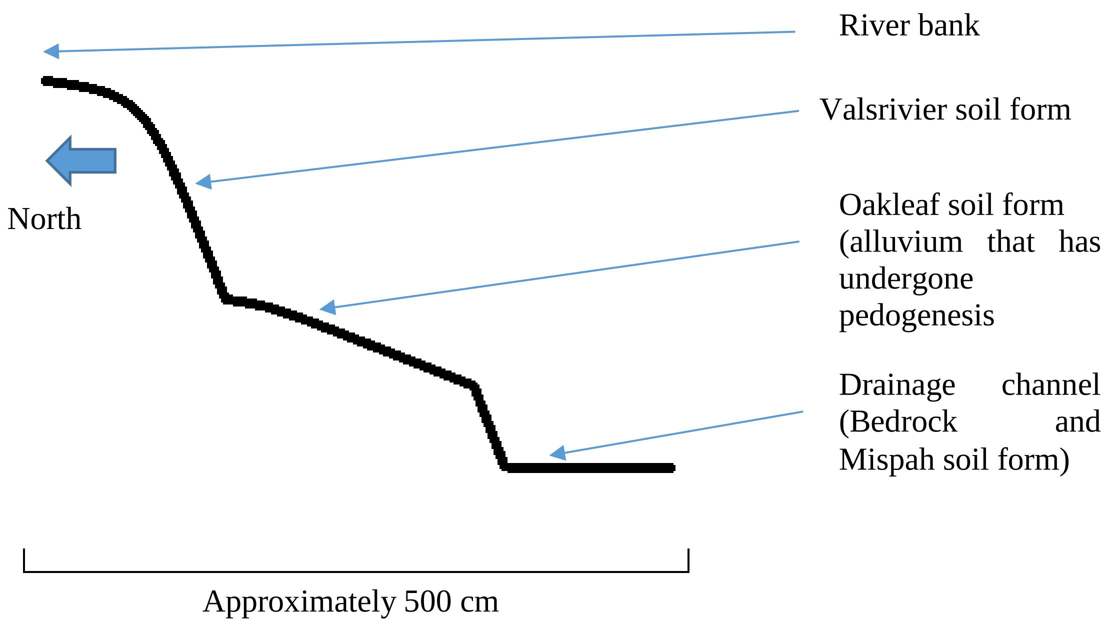

Figure 17 Soil distribution along the watercourse at point P4 (profile view)

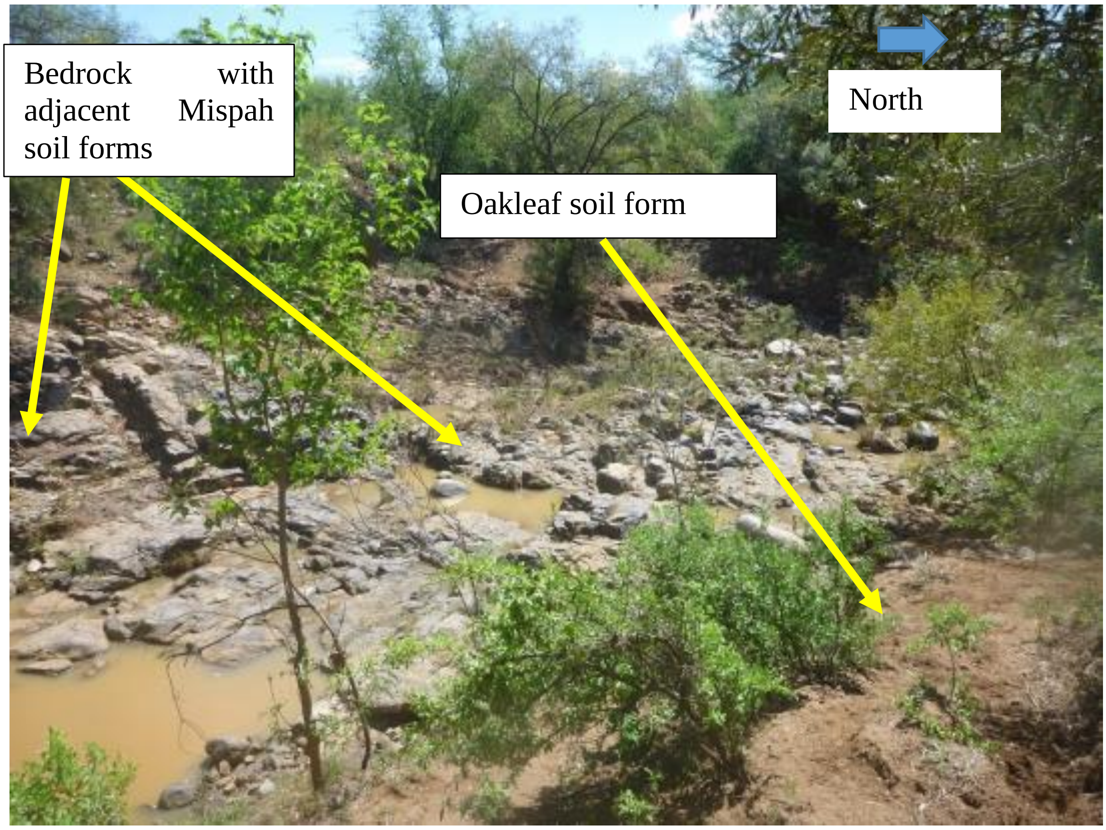

Figure 18 Soil distribution along the watercourse at point P4 (photo taken while standing on the Valsrivier soil form)

Figure 19 Colour variation in the neocutanic B-horizon

Figure 20 Red colouration of the red structured B-horizon

Figure 21 illustrates the distribution of the soil forms while **Table 2** summarises the area each soil form comprises.

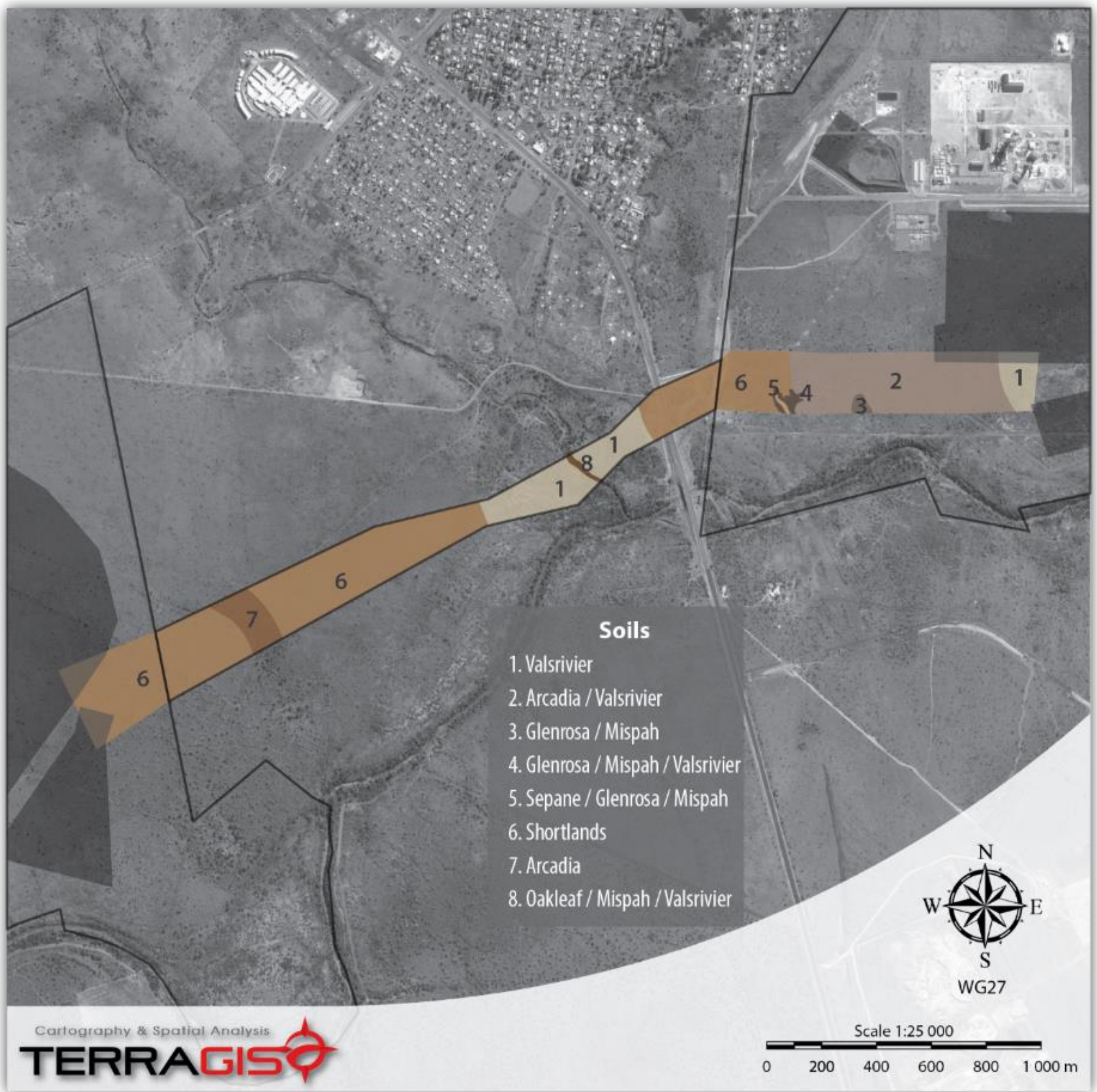

Figure 21 Soil distribution map of the area

Table 2 Area comprised by each soil form

Soil Form (Soil Complex)	**Area (ha)**
Valsrivier	11.2
Arcadia/Valsrivier	16.6
Glenrosa/Mispah	0.4
Glenrosa/Mispah/Valsrivier	0.6
Sepane/ Glenrosa/Mispah	0.1
Shortlands	42.9
Acadia	2.9
Oakleaf.Mispah/Valsrivier	0.3

4.3. Agricultural Potential linked to Land Capability Class

The soils of the study area are grouped into the following land capability classes:

- High potential arable land: The high potential agricultural land comprises the soils of the Shortlands soil form. These soils are mostly deeper than 100 cm, show a high water holding and nutrient holding capacity and adequate internal and external drainage. The soils are suited to dry-land crop production and fall into Class 1 in terms of the FAO's irrigation classes.

- Medium potential arable land: The medium potential arable land comprises the soils of the Valsrivier soil form. These soils vary in depth from 50 to 150 cm. Towards the east of the site, rocks and stones are frequently encountered in the soil profile. Internal drainage may be hampered by the swelling and shrinking action of the smectite clays. The soils do show a high nutrient and water holding capacity with adequate external drainage. These soils are suited to dry-land crop production and fall into Class 3 in terms of the FAO's irrigation classes.

- High Potential Grazing/Low to Medium Potential Arable Land: These areas comprise soils of the Arcadia and the Valsrivier/Arcadia Complex soil forms. The soils show cracking on the soil surface when dry and under such conditions, water infiltration is high. Once the soils become moist, the smectite clays swell and cracks close, resulting in a soil with a low infiltration rate, poor internal drainage and a high matrix potential. The latter results in water molecules being bound by stronger forces than in soil with a lower matrix potential. The plant available water in these soils is therefore lower in the soils of the study that exhibit a lower smectite clay content. The soils are nutrient rich, exhibit a near neutral pH and do not need to be ploughed as these soils churn themselves owing to their swelling-shrinking nature. These soils are suited to dry-land crop production. Root pruning may occur during dry spells, especially when the crops are young. The soils fall into Class 4 in terms of the FAO's irrigation classes.

- Low to Medium Potential Grazing Land/Drainage Complex: These areas comprise the Glenrosa/Mispah/Valsrivier Complex. These are shallow, rocky soils that are suited to grazing, but not crop production. These soils form part of a drainage complex.

- Low Potential Grazing land/Drainage Complex: This area comprises the Oakleaf/Mispah/Valsrivier Complex and is situated within the Sandspruit.

- Wetland/Drainage line: The Sepane/Glenrosa/Mispah Complex comprises this area. The area is a wetland system and is not suited for crop production.

Figure 22 illustrates the distribution of the land capability classes along the corridor that was surveyed while **Table 3** summarises the area each land capability class comprises.

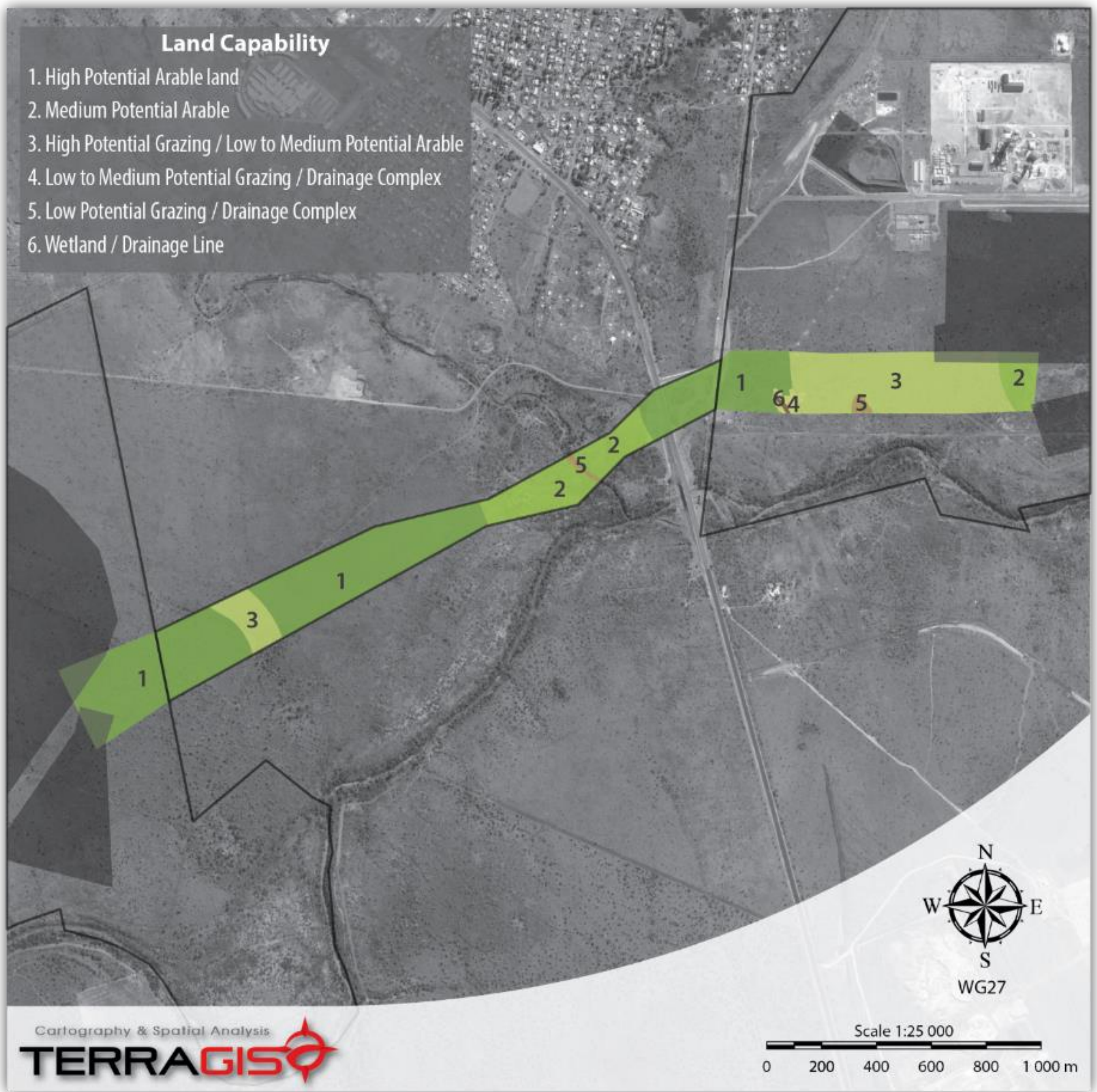

Figure 22 Land capability of the soils of the study area

4.4. Current Land Use

The area is currently used for grazing. Furrows and contouring indicated that sections of the site have been ploughed and cultivated previously.

Table 3 Area comprised by each land capability class

Land Capability Class	Soil Form (Soil Complex)	Area (ha)
High potential arable land	Shortlands	42.9
Medium potential arable land	Valsrivier	11.2
High Potential Grazing/Low to Medium Potential Arable Land	Arcadia/Valsrivier Complex Arcadia	19.6
Low to Medium Potential Grazing Land/Drainage Complex	Glenrosa/Mispah/Valsrivier Complex	0.6
Low Potential Grazing land/Drainage Complex	Oakleaf/Mispah/Valsrivier	0.7
Wetland/Drainage Complex	Sepane/Glenrosa/Mispah Complex	0.1

4.5. Area Sensitivity

Figure 23 and **Table 3** summarise the sensitivity ratings for the surveyed area. The following areas are regarded as sensitive: high potential arable land; drainage lines and wetlands; soils prone to erosion.

Table 4 Sensitivity rating correlated with soil form and land capability

Land Capability Class	Soil Form (Soil Complex)	Sensitivity	Area (ha)
Medium potential arable land	Valsrivier	Medium to high	14.2
High Potential Grazing/Low to Medium Potential Arable Land	Arcadia/Valsrivier Complex Arcadia	Medium	16.6
Low to Medium Potential Grazing Land/Drainage Complex	Glenrosa/Mispah/Valsrivier Complex	High	44.2
Low Potential Grazing land/Drainage Complex	Oakleaf/Mispah/Valsrivier	High	
Wetland/Drainage Complex	Sepane/Glenrosa/Mispah Complex	High	
High potential arable land	Shortlands	High	

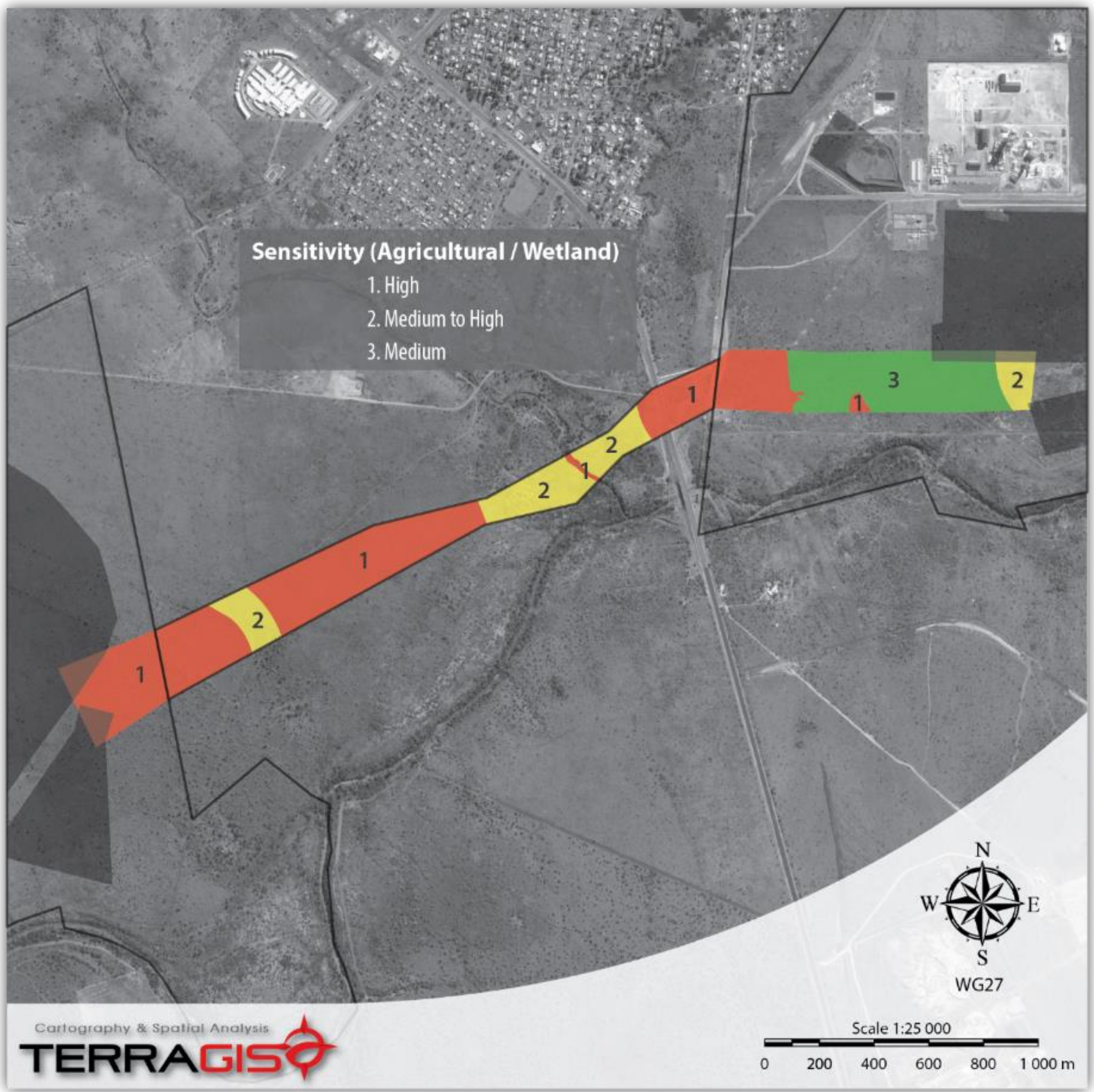

Figure 23 Sensitivity map for the study area

5. ENVIRONMENTAL IMPACT OF THE PROPOSED PIPELINE DEVELOPMENT ON THE SOIL ENVIRONMENT

5.1. Nature of Impacts

The pipeline will be constructed within a constructed "right-of-way" or servitude which is divided into a spoil side and a work side. The spoil side is the side where the soil, weathering rock and rock are stockpiled after excavation and during the construction phase. The work side is used by vehicle traffic. The right-of-way is 30 m and the pipeline length is approximately 3.8km. The right of way is usually cleared of vegetation. The tailings pipeline will be 30 cm in diameter and will be raised above ground level on plinths. The plinths will be 30 cm high. Stripping and stockpiling of soil and underlying material will only occur at the plinths.

5.1.2. Physical Impacts

Physical impacts on the soil environment relates to:

- Compaction of the soil owing to vehicle traffic;
- Erosion of the soil owing to vehicle traffic and increased surface run-off from the compacted areas;
- Localised removal of soil where the plinths are to be constructed.

Soil compaction owing to vehicle traffic is especially pronounced in areas where the soils exhibit a fine texture as is the case for most of the soils of the study area. Soil compaction results in a decrease of soil volume, aeration, water infiltration, water holding capacity, saturated hydraulic conductivity (hampers internal drainage) and an increase in soil density. This negatively impacts on plant root growth and development, thus leading to plants (crops and natural veld) being stunted and suffering from nutrient deficiencies and water stress. Culley, Dow, Presant and Maclean (1981) found that compaction in the right of way of an oil pipeline constructed in Ontoria, U.S.A, resulted in:

- Silage corn yields being approximately 50% lower during the first two years after construction in the right-of-way as opposed to adjacent areas not affected by pipeline construction;
- Smaller, but significant, lower yields were measured four years after construction in the right of way when compared to adjacent fields;
- Differences in midsummer corn and soya bean heights between the right-of-way and adjacent fields were 55% during year one after construction and 25% four years after construction.
- The impact of compaction on soil yield is significant over the first five years after construction, but considerable improvement in crop yields is noted over time.

The increased surface run-off from the compacted soils, coupled with the formation of preferential surface water flow paths owing to vehicle tracks and the highly structured nature of most soils on the site, can lead to soil erosion close to the pipeline. Soils that exhibit an abrupt transition between the A- and B-horizons, a structured A- and/or B-horizon, low organic carbon content and a fine texture are especially prone to erosion. Most soils on the study area have all or most of these characteristics.

Stripping and stockpiling of topsoil where the plinths are to be constructed will result in:

- Loss of the original spatial distribution of natural soil forms and horizon sequences which cannot be reconstructed similarly during rehabilitation, especially in an area dominated by swelling and shrinking soils;
- Loss of natural topography and drainage pattern;
- Loss of original soil depth and soil volume;
- Loss of original fertility and organic carbon content; and
- Exposure of soils to weathering, compaction, erosion, and chemical alteration of nutrients, particularly nitrogen.

5.1.3. Chemical Impacts

The TSF pipeline is envisaged to transport tailings material that could be rich in heavy metals, specifically Cr, Ni, Cu, AI, Zn, Pb, Mn and Fe, as well as sulphate, chloride, fluoride and sodium. These are elements and ions that are potentially detrimental to human health and environmental quality. Spillage of the material onto the soil surface could have far-reaching consequences, especially for nearby water courses and wetlands, as elements and ions that are toxic at high enough levels (trace amounts in the case of most heavy metals) will be leached and transported through various mechanisms into these systems.

The soils of the study area do have the capacity to buffer chemical change. The soils are high in 2:1 swelling-shrinking clays which have the capacity to sorb high levels of cationic heavy metals, especially under near neutral to slightly alkaline pH values and oxidising conditions. The Arcadia soil profiles that were examined showed lime nodules within the soil profile and one can assume that the soils of the area exhibit near neutral pH conditions. Furthermore, the high Fe oxide content of the red coloured soils (Shortlands) results in effective cationic heavy metal sequestration. With the exception of the Sepane soil form (encountered in a drainage line) all other soils formed under predominantly oxidising conditions.

For the purposes of this discussion, Cr(III) and Ni will be used to assess the capacity of the soils to sequester heavy metals during a spillage as Cr(III) is regarded as the least mobile of the cationic heavy metal group while Ni is the most mobile.

Trivalent Cr precipitates as a hydrous chrome oxide onto Fe-oxide mineral phases and adopts the crystal structure of the Fe-oxide phase to form an insoluble phase. The same hydrous chrome oxide precipitates, albeit as a less ordered mineral phase, onto smectite clays and these are only just less stable than the precipitate which forms on the Fe-oxide mineral phases.

Nickel sorption will probably be reversible, although rapid, and ionic strength dependent at pH values less than seven, indicating the formation of outer-sphere complexes or monodentate inner-sphere complexes. It precipitates as a α-$Ni(OH)_2$ onto quartz surfaces, but forms inner-sphere complexes and rather stable precipitates in the presence of sesquioxide (present at high concentrations in the Shortlands soil form) and clay minerals (present in most soil forms on the site). Ni-Al Layered Double Hydroxides (LDH) precipitated in the presence of Al-containing minerals (Scheidegger, Fendorf and Sparks, 1996; Sparks, 2003; Ford, Scheinost and Sparks 2001; Scheckel *et al*., 2000; Scheinost *et al.*, 1999; Jeon *et al*., 2003; Trivedi, Axe and Dyer, 2001, Rossouw, 2008).

The soils of the area do not have the capacity to sequester Na or anions (sulphate, chloride, fluoride) effectively. Sodium is not sorbed in high concentrations by soil mineral phases, regardless of soil pH, redox, cation exchange capacity or mineralogical composition. The anions will be mobile in these soils as South African soil, especially those dominated by 2:1 smectite clays, exhibit a net negative charge. The negatively charged anions are therefore repelled by the soil which also shows a nett negative charge.

The soils in the right-of-way will probably be highly compacted and a high percentage of spilled tailings will manifest as surface run-off during a spillage event (even in the natural state the soils of the area exhibit a low water infiltration capacity - especially when moist in the case of the Arcadia soils). Spillage of large volumes could result in tailings washing into drainage lines and ultimately nearby wetlands and water bodies.

It must be stressed that the capacity of the soils to sequester heavy metals cannot be seen as a mitigation measure in the case of a tailing spillage from the pipeline as these soils can reach a saturation point in terms of metal sequestration.

5.2. Mitigation Measures

5.2.1. Placement of the Pipeline

The single most important factor in environmental conservation practice when constructing a pipeline is the selection of the pipeline route. In the case of the study area it is proposed that the pipeline rather be constructed next to the road that runs from the concentrator plant (on the farm Frischgewaagd) to the R565 where it can meet up with the current design. This is illustrated in **Figure 24**. This amendment will result in:

- A less significant impact on the agricultural potential and land capability of the area as the area of impact for the pipeline is aligned with the area of impact for the road.
- The pipeline will be situated further away from two drainage systems on the farm Frischgewaagd (refer to soil map – **Figure 21**).
- Surface run-off from the compacted soils will be less likely to reach the drainage systems at high velocities, thus limiting soil erosion in the drainage lines. The drainage lines are more susceptible to erosion than the soils outside of these systems. Positioning the tailings pipeline further away the drainage system will lead to less severe erosion owing to surface run-off from the compacted soil. .
- Spillage from the pipelines will be less likely to reach the drainage lines from where contaminants will be transported to nearby wetlands and water bodies. The contamination plume after spillage will therefore be better contained if the spillage occurs on the farm Frischgewaagd and not near the Sandspruit.

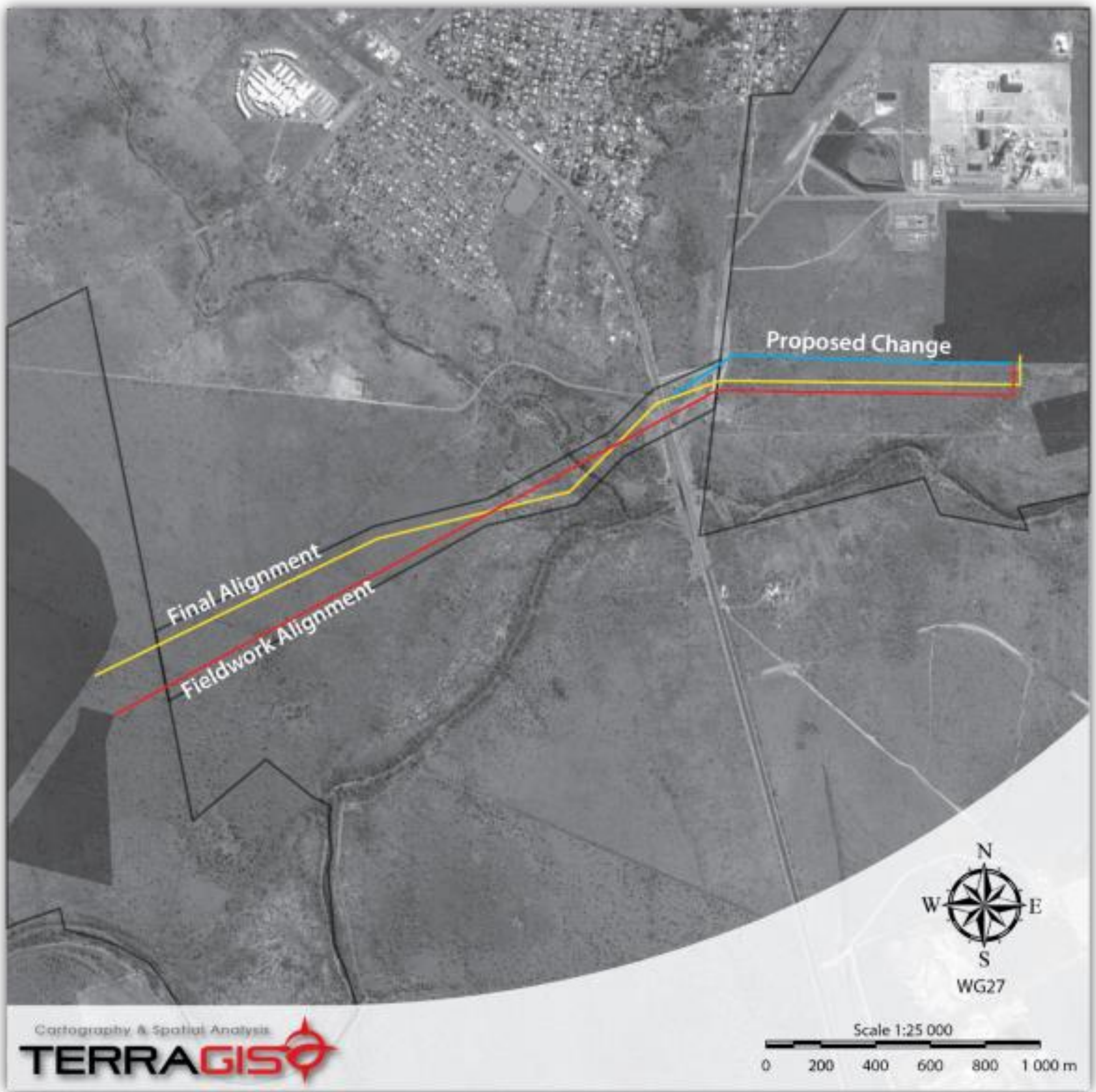

Figure 24 Proposed placement of the tailings pipeline

5.2.2. Timing of Construction

Construction should take place when the soils are dry and less prone to compaction. If construction takes place in the rainy season and when the soils are moist or saturated with water, vehicle traffic will result in rutting (sometimes to the extent that A- and B-horizons mix), excessive wheel slip will occur, puddles may form and tracks are more easily entrenched into the soil when the vehicles leave the right–of-way.

5.2.3. Stripping and Stockpiling of Excavated Soil

Soils should be excavated in such a way that the A-, B- and C-horizons are stripped and stockpiled separately. During stock-piling the organic matter in the soil decomposes, microbial activity decreases and plant seeds and microbial survival structures lose viability with time. It is therefore recommended that stockpiles are utilised as soon as possible and that erosion of stockpile material be managed (slope and orientation of stockpile, movement of surface water etc.).

After plinth construction and if in-filling of the pits that was dug for plinth construction is needed, the soils should be placed in the pits in such a way that the horizon sequence resembles that of the soil prior to excavation. This means, the C-horizon must first be placed after which the B-horizon will be placed and lastly the A-horizon will be placed, thus ensuring the most fertile soil layer being on top and least fertile layer at the bottom. The remainder of the soil can be distributed on the right-of-way. A 30 m right-of-way is stipulated for this pipeline. Once the pipeline has been constructed a five meter service road should be adequate and the rest of the disturbed area should be rehabilitated.

5.2.4. Rehabilitation of Compacted Soil

The majority of soils of the study area swell and shrink markedly in response to moisture changes. The soils that have been compacted should therefore be left and the compaction level monitored. Over time the natural churning action of the soils will result in the compaction layer breaking apart. This may, however, happen for an extended period of time.

The compacted soils, especially outside of the service road, can be ripped to a depth that will break the compaction layer. If vegetation cover does not return in a reasonable amount of time, mulching and seeding should be considered. The return of vegetation to the compacted area should be compared to areas where vegetation have been cleared, but the soils not compacted when deciding when ripping becomes a viable option. Ripping of the soil should be seen as a last resort in remediating soil compaction as it could lead to soil erosion in this environment. Prior to ripping, a soil scientist should assess the situation and investigate whether or not the natural churning action of the soils will be able to break up the compaction layer.

5.2.5. Mitigation of Spillage

The tailings pipeline must be maintained and regularly inspected in order to prevent spillages from occurring owing to negligence. In the case of an unforeseen spillage occurring, the following should be implemented:

- Repair the leakage;
- Contain the spill using berms and swales;
- Remove the tailings from the soil surface;
- Contact a soil pollution expert to sample and analyse the soils and determine the nature and severity of the pollution, as well as to compile a remediation plan.

5.3. Impact Rating

Table 5 summarises the impact rating assigned to each of the identified impacts if mitigation measures are not implemented. **Table 6** summarises the impact rating if mitigation measures are to be implemented. For details regarding the nature of the impact, the severity, duration, spatial scale, consequence, probability and significance of each impact, the reader is referred to Appendix A.

Table 5 Impact rating before mitigation

Impact	Severity	Duration	Spatial scale	Consequence	Probability	Significance
Compaction	H	M	L	M	H	M
Erosion	M	H	H	H	H	H
Soil Stripping	M	M	L	M	H	M
Soil Pollution (Spillage)	H	H	H	H	H	H

Table 6 Impact rating with mitigation measures in place

Impact	Severity	Duration	Spatial scale	Consequence	Probability	Significance
Compaction	M	M	L	M	H	M
Erosion	L	H	L	M	L	L
Soil Stripping	L	M	L	L	H	M[1]
Soil Pollution (Spillage)	H	H	M	H	H	H[2]

[1]This rating should rather read low to medium.

[2]If spillage occurs the impact significance will be high. Mitigation measures implemented when this occurs will limit the extent of the impact, but not the severity. If spillage does not occur there is no impact. This impact is therefore preventable.

5.4. Final Statement

If the mitigation measures are implemented, there is no reason why the project cannot continue.

6. SUMMARY AND CONCLUSION

6.1. Introduction

Wesizwe is the owner of Bakubung Platinum Mine, currently shaft sinking on the farm Frischgewaagd 96JQ (Portions 3, 4 and 11). The mine is located near Ledig, just south of the Pilanesberg National Park and Sun City in the North West Province.

Wesizwe is proposing to make several changes to the approved mine. The changes are required in order to cater for an increase in ore processing capacity, as well as additional support infrastructure which will require additional Environmental Authorisations, a WML and additional water uses requiring an amendment to their existing WUL.

Amongst these changes is the proposed construction of an approximately 3.83km long tailings pipeline (with a return water pipeline) linking the concentrator plant to the TSF. The alignment will be situated on the Farms Frischgewaagd and Mimosa and the intervening area to the north of the Elands River between these farms. The pipeline will be constructed within a constructed “right-of-way” or servitude which is divided into a spoil side and a work side. The spoil side is the side where the soil, weathering rock and rock are stockpiled after excavation and during the construction phase. The work side is used by vehicle traffic. The right-of-way is 30 m wide and the pipeline length is 3.83 km. The right-of-way is usually cleared of vegetation. The pipeline will have a 30 cm diameter and will be raised above ground level on plinths. The plinths will be 30 cm high. Stripping and stockpiling of soil and underlying material will only occur at the plinths.

6.2. Aim of the Study

This report deals with the potential impact that the tailings pipeline could have on the land use, land capability and agricultural potential of the area during and after construction.

6.3. Methodology

The study area was traversed and observations regarding the landscape and occurrence of soils were made continuously. Augering was done to a maximum of 1500 mm. In some cases the occurrence of rocks and highly structured soil material hampered deep augering. The soils were classified according to the South African Soil Classification System (MacVicar *et al.,* 1994) and land capability classes where assigned to each soil form.

6.4. Results and Discussion

6.4.1. Soil Form and Land Capability

The soils of the area are grouped into the following land capability classes;

- High potential arable land: The high potential agricultural land comprises the soils of the Shortlands soil form. These soils are mostly deeper than 100 cm, show a high water holding and nutrient holding capacity and adequate internal and external drainage. The soils are suited to dry-land crop production and fall into Class 1 in terms of the FAO's irrigation classes.

- Medium potential arable land: The medium potential arable land comprises the soils of the Valsrivier soil form. These soils vary in depth from 50 to 150 cm. Towards the east of the site, rocks and stones are frequently encountered in the soil profile. Internal drainage may be hampered by the swelling and shrinking action of the smectite clays. The soils do show a high nutrient and water holding capacity with adequate external drainage. These soils are suited to dry-land crop production and fall into Class 3 in terms of the FAO's irrigation classes.

- High Potential Grazing/Low to Medium Potential Arable Land: These areas comprise soils of the Arcadia and the Valsrivier/Arcadia Complex soil forms. The soils show cracking on the soil surface when dry and under such conditions, water infiltration is high. Once the soils become moist, the smectite clays swell and cracks close, resulting in a soil with a low infiltration rate, poor internal drainage and a high matric potential. The latter results in water molecules being bound by stronger forces than in soil with a lower matric potential. The plant available water in these soils is therefore lower in the soils of the study that exhibit lower a smectite clay contents. The soils are nutrient rich, exhibit a near neutral pH and do not need to be ploughed as these soils churn themselves owing to their swelling-shrinking nature. These soils are suited to dry-land crop production. Root pruning may occur during dry spells, especially when the crops are young. The soils fall into Class 4 in terms of the FAO's irrigation classes.

- Low to Medium Potential Grazing Land/Drainage Complex: These areas comprise the Glenrosa/Mispah/Valsrivier Complex. These are shallow, rocky soils that suited to grazing, but not crop production. These soils form part of a drainage complex.

- Low Potential Grazing land/Drainage Complex: This area comprises the Oakleaf/Mispah/Valsrivier Complex in is situated within the Sandspruit.

- Wetland/Drainage line: The Sepane/Glenrosa/Mispah Complex comprises this area. The area is a wetland system and is not suited for crop production.

6.4.2. Impact of the Pipeline on the Soil Environment

The tailings could have both physical and chemical impacts on the soil environment. These relate to:

- Compaction of the soil owing to vehicle traffic;
- Erosion of the soil owing to vehicle traffic and increased surface run-off from the compacted areas;
- Localised removal of soil where the plinths are to be constructed and
- The pipeline is envisaged to transport tailings material that could be rich in heavy metals, specifically Cr, Ni, Cu, AI, Zn, Pb, Mn and Fe, as well as sulphate, chloride, fluoride and sodium. These are elements and ions that are potentially detrimental to human health and environmental quality. Spillage of the material onto the soil surface could have far-reaching consequences, especially for nearby water courses and wetlands.

6.4.3. Mitigation Measures

The impact of the pipeline can be mitigated through the following means;

- Placement of the pipeline in an area where the impact on the environment will be a minimum;
- Construction to be conducted when the soils are dry;
- Soil horizons to be stripped and stockpiled correctly and back-filled as soon as possible;
- Rehabilitation of the compacted soils through ripping;
- Prevention of spillage through proper maintenance of the pipeline; and
- In the event of a spill, the leak must be repaired, the tailings contained and a specialist must be contracted to conduct a soil pollution and remediation assessment.

6.5. Recommendations

The single most important factor in environmental conservation practice when constructing a pipeline is the selection of the pipeline route. In the case of the study area it is proposed that a section of the pipeline rather be constructed next to the road that runs from the concentrator plant (on the farm Frischgewaagd) to the R565 where it can meet up with the current design. This will minimise the impact on the agricultural potential of the area and limit the risk of erosion occurring along the drainage lines on the farm Frischgewaagd, as well the risk of tailings material entering a drainage system in the case of a spillage event. If the mitigation measures are implemented, there is no reason why the project cannot continue.

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APPENDIX A IMPACT RATING AND DISCUSSION

IMPACT TYPE: SOIL COMPACTION

RATING OF IMPACT

Nature of Impact

Soil compaction owing to vehicle traffic is especially pronounced in areas where the soils exhibit a fine texture as is the case for most of the soils of the study area. Soil compaction results in a decrease of soil volume, aeration, water infiltration, water holding capacity, saturated hydraulic conductivity (hampers internal drainage) and an increase in soil density.

Severity

The severity of the impact of soil compaction on the land capability of the area is high. Soil compaction negatively impacts on plant root growth and development, thus leading to plants (crops and natural veld) being stunted and suffering from nutrient deficiencies and water stress. Culley, Dow, Presant and Maclean (1981) found that compaction in the right of way of an oil pipeline constructed in Ontoria, U.S.A, resulted in:

- Silage corn yields being approximately 50 % lower during the first two years after construction in the right-of-way as opposed to adjacent areas not affected by pipeline construction;
- Smaller, but significant, lower yields were measured four years after construction in the right of way when compared to adjacent fields;
- Differences in midsummer corn and soya bean heights between the right of way and adjacent fields were 55 % during year one after construction and 25 % four years after construction.
- The impact of compaction on soil yield is significant over the first five years after construction, but considerable improvement in crop yields is noted over time.

After mitigation measures have been put in place the rating is medium.

Duration

Soil compaction can be reversed. The soils of the area are mostly of a swelling-shrinking nature and this will eventually mitigate the soil compaction effect (if no other mitigation measure is taken). The duration will probably be for the duration of the project and is ranked as medium.

Spatial scale/Extent

Soil compaction will occur in the 30m right of way. It is thus localised. The rating is low prior and after mitigation.

Consequence

The consequence of the impacts is medium prior to mitigation and medium after.

Probability

Even if mitigation measures are put in place, the probability of compaction occurring is high.

Significance

The significance rating is medium prior and after mitigation, although the severity is medium after mitigation as opposed to high before.

Overall mitigation objectives for each assessed impact or group of impacts:

- Placement of the pipeline in an area where the impact on the environment will be a minimum.
- Construction to be conducted when the soils are dry.

Mitigation measures:

- Place pipeline in areas already transformed or where transformation will occur owing to road construction etc.
- Construct in dry season.
- Avoid vehicle slippage and rutting.

Mitigation type

These measures are all control types.

The degree to which the impact can –

- **be reverse**d: Partially
- **cause irreplaceable loss of resource:** Moderate
- **be avoided, managed or mitigated:** The impact cannot be avoided, but can be managed

Monitoring recommendations:

- Inspection of compacted areas after construction has been completed.
- Inspection of compacted areas every three months after construction. Compaction should be measured using a penetrometer or similar instrument.
- A soil scientist should recommend whether or not ripping of the soils should be done after a year of monitoring. This decision must be based on the monitoring data.

<u>IMPACT TYPE: SOIL EROSION</u>

RATING OF IMPACT

Nature of Impact

The increased surface run-off from the compacted soils, coupled with the formation of preferential surface water flow paths owing to vehicle tracks and the highly structured nature of most soils on the site, can lead to soil erosion close to the pipeline. Soils that exhibit an abrupt transition between the A- and B-horizons, a structured A- and/or B-horizon, low organic carbon content and a fine texture are especially prone to erosion. Most soils on the study area have all or most of these characteristics. Soil erosion of the drainage complexes are a concern.

Severity

The severity of the impact of soil erosion on the land capability of the area is high. Soil erosion leads to soils being lost for agricultural use and it negatively impacts on the biodiversity of the natural veld. Erosion of the drainage complexes will lead to soil loss within these systems, but will also result in silting of dams, pans and river systems downstream of the study area. The severity rating is regarded as medium prior to mitigation and low after.

Duration

The duration is ranked as high prior and after mitigation Soil compaction could extend passed the life of mine.

Spatial scale/Extent

Soil erosion could occur beyond the 30m right-of-way and area of direct impact. This is especially of concern if construction results in the erosion of the drainage complexes. The spatial extent is on a regional scale and ranked as high. If mitigation measures are put in place (especially moving the tailings pipeline away from drainage complexes), the impact will be low as the spatial extent will be local.

Consequence

The consequence of the impacts is high prior to mitigation and medium after.

Probability

The probability of erosion occurring is high prior to mitigation measures taking place and low if mitigation measures are put in place.

Significance

The significance rating is high medium prior mitigation and low after mitigation.

Overall mitigation objectives for each assessed impact or group of impacts:

- Placement of the pipeline away from drainage lines on the farm Frischgewaagd.
- Limit soil compaction.

Mitigation measures:

- Place pipeline away from the drainage lines on the farm Frischgewaagd, especially where the Sepane soil form occurs.
- Construct in dry season.
- Avoid vehicle slippage and rutting.
- If soil erosion has occurred, an erosion control plan entailing hard (i.e. gabion construction) and/or soft (i.e. breaking surface water flow velocities) should be designed by a competent person.

Mitigation type

These measures are all control types with the exception of the design of an erosion control plan which is a remedy.

The degree to which the impact can –

- **be reverse**d: Partially
- **cause irreplaceable loss of resource:** Possible
- **be avoided, managed or mitigated:** The impact cannot be avoided, but it can be managed

Monitoring recommendations:

- Inspection of the impacted area on a regular basis (every month in the rainy season and every three months in the dry season).

IMPACT TYPE: SOIL STRIPPING AND STOCKPILING

RATING OF IMPACT

Nature of Impact

Soil stripping entails the removal and stockpiling of the soils during plinth construction.

Severity

The severity on the soil environment is ranked as medium. Stripping and stockpiling of topsoil where the plinths are to be constructed will result in:

- Loss of the original spatial distribution of natural soil forms and horizon sequences which cannot be reconstructed similarly during rehabilitation, especially in an area dominated by swelling and shrinking soils.
- Loss of natural topography and drainage pattern.
- Loss of original soil depth and soil volume.
- Loss of original fertility and organic carbon content.
- Exposure of soils to weathering, compaction, erosion, and chemical alteration of nutrients, particularly nitrogen.

After mitigation, the impact is rated as low.

Duration

The duration is ranked as medium (prior and after mitigation) as the impact the tailings pipeline will be in place for at least the life of mine.

Spatial scale/Extent

The impact will be localised and restricted (impact rated as low prior to and after mitigation) to the area to be excavated for plinth construction.

Consequence

The consequence of the impacts is medium prior to mitigation and low after.

Probability

The probability of soil being stripped and stockpiled is high.

Significance

The significance rating is medium prior mitigation and medium after mitigation even though the consequence of the impact is medium prior to mitigation and low after mitigation.

Overall mitigation objectives for each assessed impact or group of impacts:

- Soil horizons to be stripped and stockpiled correctly and back-filled as soon as possible.

Mitigation measures:

- Soil horizons to be stripped separately.
- Soil horizons to be stockpiled separately.
- C-horizon material to be backfilled first followed by B- and A-horizon material.

Mitigation type

These measures are control type mitigation measures.

The degree to which the impact can –

- **be reversed**: Not reversable. The tailings pipeline will be on site for at least as long as the mine is operational. The soils where the plinths are to be constructed will therefore only be back-filled if and when the pipeline is removed and the area rehabilitated. It is doubtful that the stockpiling of these soils will be successful for such a long period of time as rainfall and wind will erode the stockpiles.
- **cause irreplaceable loss of resource:** The construction of the pipeline will not cause an irreplaceable loss of arable land through stripping and stockpiling.
- **be avoided, managed or mitigated:** The impact cannot be avoided, but can be managed

IMPACT TYPE: SOIL POLLUTION OWING TO SPILLAGE

RATING OF IMPACT

Nature of Impact

The pipeline is envisaged to transport tailings material that could be rich in heavy metals, specifically Cr, Ni, Cu, AI, Zn, Pb, Mn and Fe, as well as sulphate, chloride, fluoride and sodium. These are elements and ions that are potentially detrimental to human health and environmental quality. Spillage of the material onto the soil surface could have far-reaching consequences, especially for nearby water courses and wetlands.

Severity

The soils of the study area do have the capacity to buffer chemical change. The soils are high in 2:1 swelling-shrinking clays which have the capacity to sorb high levels of cationic heavy metals, especially under near neutral to slightly alkaline pH values and oxidising conditions. The Arcadia soil profiles that were examined showed lime nodules within the soil profile and one can assume that the soils of the area exhibit near neutral pH conditions. Furthermore, the high Fe oxide content of the red coloured soils (Shortlands) results in effective cationic heavy metal sequestration. With the exception of the Sepane soil form (encountered in a drainage line) all other soils formed under predominantly oxidising conditions.

For the purposes of this discussion, Cr(III) and Ni will be used to assess the capacity of the soils to sequester heavy metals during a spillage as Cr(III) is regarded as the least mobile of the cationic heavy metal group while Ni is the most mobile.

Trivalent Cr precipitates as a hydrous chrome oxide onto Fe-oxide mineral phases and adopts the crystal structure of the Fe oxide phase to form an insoluble phase. The same hydrous chrome oxide precipitates, albeit as a less ordered mineral phase, onto smectite clays and these are only just less stable than the precipitate which forms on the Fe-oxide mineral phases.

Nickel sorption will probably be reversible, although rapid, and ionic strength dependent at pH values less than seven, indicating the formation of outer-sphere complexes or monodentate inner-sphere complexes. It precipitates as a α-$Ni(OH)_2$ onto quartz surfaces, but forms inner-sphere complexes and rather stable precipitates in the presence of sesquioxide (present at high concentrations in the Shortlands soil form) and clay minerals (present in most soil forms on the site). Ni-Al layered double hydroxides (LDH) precipitated in the presence of Al-containing minerals (Scheidegger, Fendorf and Sparks, 1996; Sparks, 2003; Ford, Scheinost and Sparks 2001; Scheckel *et al*., 2000; Scheinost *et al.*, 1999; Jeon *et al*., 2003; Trivedi, Axe and Dyer, 2001, Rossouw, 2008.

The soils of the area do not have the capacity to sequester Na or anions (sulphate, chloride, fluoride) effectively. Sodium is not sorbed in high concentrations by soil mineral phases, regardless of soil pH, redox, cation exchange capacity or mineralogical composition. The anions will be mobile in these soils as South African soil, especially those dominated by 2:1 smectite clays, exhibit a net negative charge. The negatively charged anions are therefore repelled by the soil which also shows a nett negative charge.

The soils in the right-of-way will probably be highly compacted and a high percentage of spilled tailings will manifest as surface run-off during a spillage event (even in the natural state the soils of the area exhibit a low water infiltration capacity - especially when moist in the case of the Arcadia soils). Spillage of large volumes could result in tailings washing into drainage lines and ultimately nearby wetlands and water bodies.

It must be stressed that the capacity of the soils to sequester heavy metals cannot be seen as a mitigation measure in the case of tailing spillage from the pipeline as these soils can reach a saturation point in terms of metal sequestration.

The severity for the mitigated and unmitigated scenario is ranked as high.

Duration

Soil contamination, in the case of a spill, could extend well past the life of mine. The duration is ranked as high even if mitigation measures are implemented

Spatial scale/Extent

The pollution plume may slowly migrate through the soils to reach underground water bodies or nearby wetlands and drainage lines. In the case of a spill of large volumes, overland flow may result in tailings entering a drainage line and the extent of the pollution reaching far beyond the site boundaries. The spillage volume is the driving force behind the extent of the impact. In the case of a quick response time which results in closing of the pipeline so that further spillage does not occur, the spatial extent can be contained to a localised or even local level. Owing the severity of this type of impact, a conservative approach is followed and the mitigated impact is regarded as medium.

Consequence

The consequence of this impact is high prior to mitigation and high after.

Probability

The probability of a leak occurring along the pipeline somewhere during the life of mine is high. The probability of the tailings having a negative impact on the soil environment within and beyond the site boundary is high regardless of the mitigation measures implemented during and after spillage

Significance

The significance rating is high prior to mitigation and high after mitigation.

Overall mitigation objectives for each assessed impact or group of impacts:

- Avoid spillage occurring.
- Contain spill and pollution plume when spillage has occurred.

Mitigation measures:

- Maintain pipeline in order to avoid spillage.
- If spillage occurs, the spill must be contained with swales and berms after the leakage has been repaired, the spilled material should be removed and pollution plume should be determined a soil chemist and hydrologist.
- A remediation plan must be compiled by the soil chemist and hydrologist.

Mitigation type

Maintenance of the pipeline is a control measure whereas the other actions are remedial actions.

The degree to which the impact can –

- **be reversed**: Spillage and soil pollution cannot be reversed. The extent of the impact (if it occurs) can be managed through the implementation of mitigation measures. The success of such a management plan will be subject to spill volume, tailings composition and soil-contaminant interactions. At best these measures will have an effect on the spatial extent of the contamination, but not on its severity.
- **cause irreplaceable loss of resource:** Definite
- **be avoided, managed or mitigated:** The impact can be avoided if the pipeline is maintained.

APPENDIX B CURRICULUM VITAE

CURRICULUM VITAE

1. **Name:** Petrus Stephanus Rossouw (PS/Mafunyane)

2. **Date of birth:** 9 February 1981

3. **ID number:** 8102095032088

4. **Languages:** Afrikaans (fluent), English (fluent), Sepedi/Sesotho/Setswana (Basic)

5. **Education:**

Institution	Degrees obtained
University of Pretoria (UP) (2008)	M.Sc. Agric. Soil Science ▪ Thesis title: Environmental extractability of chromium and nickel from soils of South Africa's Eastern Highveld ▪ Courses passed on 700 level: Soil chemistry, soil physics, plant nutrition and soil fertility
University of Pretoria (UP) (2004)	B.Sc. Agric. Soil Science ▪ Advanced courses: Soil chemistry, soil physics, soil dynamics, soil mineralogy and pedology, soil classification, soil water relations, natural product chemistry; environmental chemistry, physical chemistry, organic chemistry, inorganic chemistry, analytical chemistry.
	Courses passed for non-degree purposes
University of South Africa (UNISA) (2006 to 2008)	Advanced courses in Literary Theory, Theory of Poetry, Theory of Narrative, Theory of Drama, Creative writing (Afrikaans)
University of Pretoria (UP) (2004 to 2006)	Advanced courses in Afrikaans Text Editing, History of Afrikaans Poetry and History of Afrikaans Prose
	Short courses
University of Pretoria (UP) (Oct 2013)	Scanning electron microscopy-energy dispersive spectroscopy (SEM-EDS) and applications to environmental earth sciences
University of KwaZulu-Natal (UKZN) (Des 2010)	Advanced modelling of water flow and solute transport in the vadose zone with Hydrus

6. **Special interests:** Forensic soil chemistry, soil pollution assessment (including transport mechanisms), geochemical and hydropedological modelling, assessing chemical and hydrological functioning of natural and artificial wetland systems, mine drainage and industrial effluent treatment using passive/low energy input systems, constructed wetland design (including chemical transformation of material used in construction).

7. **Specialised skills:** Understanding of environmental soil and water chemistry, critical evaluation of laboratory analytical procedures and development of specialised analytical methods for understanding project specific problems, laboratory and field based experimental design, water flow (saturated and unsaturated) and solute transport modelling in the vadose zone with the Hydrus 1D

and Hydrus 2D/3D programs, chemical modelling with the PHREEQC code, wetland delineation in problematic areas (i.e. Johannesburg dome granites), report writing, project management.

8. **Experience:**

Date:	**Nov 2006 to May 2010**
Organisation:	Department of Plant Production and Soil Science, University of Pretoria
Position:	Research assistant
Date:	**2006 to June 2010**
Organisation:	TerraFirma Soil Science cc
Position:	Soil Scientist (Founding member/Co-director)
Date:	**Jul 2010 to April 2012**
Organisation:	Terra Soil Science cc
Position:	Environmental soil chemist and hydropedologist
Date:	**Mei 2012 to current**
Organisation:	Rossouw and Associates - Soil and Water Science (Pty) Ltd
Position:	Director

9. **Society membership:** The South African Counsel for Natural Scientific Professionals (Registration number: 400194/12), Soil Science Society of Southern Africa (SSSSA), South African Soil Surveyors Organisation (SASSO), South African Wetland Society (SAWS)

10. **Presentations at national and international conferences:**

- Rossouw, P.S. 2011. Blue-green colouration in soil and its implications for understanding wetland hydrology. Wetland Indaba, Didima lodge, Drakensberg, KwaZulu-Natal, South Africa
- Rossouw, P.S., De Jager, P.C., Van der Waals, J.H. 2011. Chromium(III) and nickel extractability as influenced by soil water potential levels. Annual Combined Conference of the SASCP, SAWSS, SSSSA and SASHS, Pretoria, Gauteng, Republic of South Africa.
- Rossouw, P.S., De Jager, P.C., Claassens, A.S. 2008. The influence of an external source of silicon on chromium(III) and nickel extractability. Silicon in Agriculture Conference, Wild Coast Sun, Republic of South Africa.
- Rossouw, P.S., De Jager, P.C., Claassens, A.S. 2007. The extractability of chromium(III) and nickel as influenced by wetting and drying cycles in soil. Tenth International Symposium on Soil and Plant Analysis, Budapest, Hungary.
- Rossouw, P.S., De Jager, P.C. Van der Waals, J.H. 2007. Chromium and nickel transformation on soil mineral surfaces. Annual Combined Conference of the SASCP, SAWSS, SSSSA and SASHS, Badplaas, Mpumalanga, Republic of South Africa.
- Van der Waals, J.H., Rossouw, P.S., Potgieter, J.J.C., De Jager, P.C. 2007. Uranium mobility in soil. Annual Combined conference of the SASCP, SAWSS, SSSSA and SASHS, Badplaas, Mpumalanga, Republic of South Africa.

11. **Project grouping:**

Research projects (2006 to 2010) – Funded by The South African Institute for Steel and Iron (SAISI)
▪ Heavy metal dynamics in the soil environment ▪ First draft guidelines for the sustainable use of steel plant slag (aglime) in agriculture ▪ The phyto-availability of heavy metals
Research projects (2012 to 2014) – In collaboration with the University of Pretoria (UP)
▪ Treatment of sulphate and heavy metal containing mine water using low energy input systems ▪ Sulphur and heavy metal dynamics in constructed wetland and floating wetland systems
Consultancy projects (2006 to current)
▪ Soil and surface water pollution status assessment (heavy metals, salinization, hydrocarbons, biocides and asbestos) from coal washing plants, coal stockpiles, discard gold mine tailings dams, slag storage areas, zinc refinery plants, copper and chrome smelters, fertiliser storage facilities, cattle feedlot areas, sewage plants and railroad facilities, including proposals for remediation and/or mitigation ▪ The capacity of wetland systems (soil) to buffer chemical change in polluted environments (pollution emanating from coal mines, gold mines, steel plants and feedlots) ▪ Assessment of the chemical and hydrological functioning of wetland/peatland/mire systems ▪ Design of passive or low energy input systems to treat Cr(VI), F, NO_3 and SO_4 contaminated water ▪ Feasibility assessment of bioreactor systems for treating mine drainage from coal mine pits ▪ Artificial wetland design to replace existing wetland systems post-mining ▪ Assessment of the chemical transformation (including pollution status) of soils/sediments in artificial wetland and lake system ▪ Suitability assessment of soils and saprolitic materials for use as water impermeable layers and topsoil layers to support vegetation in the rehabilitation of industrial waste dumps ▪ Wetland delineation (pedological and hydropedological studies) ▪ Baseline soil, land use, land capability and agricultural potential surveys (pedological studies) and impact assessments of mining, power line, housing, solar and wind power developments. (Completed more than 200 projects)

12. **Workshops attended:**

- World Reference Base for Soils Workshop, Siberia, Russia. August 2013. Diversity of soils of cold ultra-continental climate. Russian Academy of Science.
- South African Soil Classification. Attends a number of workshops per year (for the past five years). South African agricultural and/or wetland soils. South African Soil Surveyors Organisation (SASSO)

13. **Other information:**

- Served on the reference committee of projects K5/2102 and K5/2052 of the Water Research Commission (WRC)
- Co-supervisor for a honours degree study conducted at the University of Pretoria on sulphur dynamics in floating wetland systems (L. Madiseng, 2013)

14. Short courses completed not relating to natural science:

- Film camera and lighting (2010) – CityVarsity, Johannesburg
- Creativity and creative writing: CE@UP, University of Pretoria (2008); Dr Riana Scheepers (2009)

15. Contact information:

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16. References:

- Mr Chris de Jager (Soil science lecturer at the University of Pretoria):
  082 465 2370 / chris.dejager@up.ac.za
- Dr Piet-Louis Grundling (Consultant and researcher associated with the University of Free State):
  072 793 8248 / peatland@mweb.co.za