environmental affairs

Department:
Environmental Affairs
REPUBLIC OF SOUTH AFRICA

DETAILS OF SPECIALIST AND DECLARATION OF INTEREST

	(For official use only)
File Reference Number:	12/12/20/ or 12/9/11/L
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Date Received:	

Application for integrated environmental authorisation and waste management licence in terms of the-

(1) National Environmental Management Act, 1998 (Act No. 107 of 1998), as amended and the Environmental Impact Assessment Regulations, 2010; and

(2) National Environmental Management Act: Waste Act, 2008 (Act No. 59 of 2008) and Government Notice 718, 2009

PROJECT TITLE

Proposed 30-year Ash Disposal Facility at Kendal Power Station, Mpumalanga

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4.2 The specialist appointed in terms of the Regulations_

I, Ian Jones, declare that --

General declaration:

I act as the independent specialist in this application;
I will perform the work relating to the application in an objective manner, even if this results in views and findings that are not favourable to the applicant;
I declare that there are no circumstances that may compromise my objectivity in performing such work;
I have expertise in conducting the specialist report relevant to this application, including knowledge of the Act, Regulations and any guidelines that have relevance to the proposed activity;
I will comply with the Act, Regulations and all other applicable legislation;
I have no, and will not engage in, conflicting interests in the undertaking of the activity;
I undertake to disclose to the applicant and the competent authority all material information in my possession that reasonably has or may have the potential of influencing - any decision to be taken with respect to the application by the competent authority; and - the objectivity of any report, plan or document to be prepared by myself for submission to the competent authority;
all the particulars furnished by me in this form are true and correct; and
I realise that a false declaration is an offence in terms of regulation 71 and is punishable in terms of section 24F of the Act.

Signature of the specialist:

Earth Science Solutions (Pty) Ltd

Name of company (if applicable):

20th MAY 2016

Date:

BASELINE, EIA & EMP – FINAL REPORT6

Project No: WC.KPS.S.12.08.00

ESKOM HOLDINGS SOC (PTY) LTD
KENDAL 30 YEAR ASH DISPOSAL FACILITY EXPANSION PROJECT

BASELINE INVESTIGATION
ENVIRONMENTAL IMPACT ASSESSMENT
AND
MANAGEMENT PLAN

SPECIALIST SOILS, LAND CAPABILITY & AGRICULTURAL POTENTIAL STUDIES

Compiled For

August 2016

Sustaining the Environment

ESKOM HOLDINGS SOC LTD
KENDEL 30 YEAR ASH DISPOSAL PROJECT

Compiled for
Zitholele Consulting

Report Number: **Baseline, EIA & EMP – Specialist Soils, Land Capability & Agricultural Potential Studies – Final Report**

Client: **Zitholele Consulting**
Attention: **Ms. Tania Oosthuizen**

DOCUMENT ISSUE STATUS

Report Name	**Eskom Holdings Ltd – Kendel 30 Year Ash Disposal Facility - Environmental Impact Assessment Project Baseline Soils, Agricultural Potential and Land Capability Specialist Studies**			
Report Number	**WC.KD.S.12.04.00**			
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Carried Out By	**Earth Science Solutions (Pty) Ltd**			
Commissioned By	**Zitholele Consulting**			
Title	**Name**	**Capacity**	**Signature**	**Date**
Author	Ian Jones	Director ESS (Pty) Ltd		August 2016
Project Director	Tania Oosthuizen	Project Leader		
Technical Review				

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Our Ref: ZC.WD.S.12.04.00
Your Ref: Order No. 12810

10th August 2016

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Attention: Tania Oosthuizen.

Dear Tania,

Re: ESKOM HOLDINGS LTD
KENDAL 30 YEAR ASH DISPOSAL FACILITY - EXPANSION PROJECT
BASELINE SOIL, LAND CAPABILITY AND AGRICULTURAL POTENTIAL STUDIES, ENVIRONMENTAL IMPACT ASSESSMENT AND MANAGEMENT PLAN

Attached herewith please find the baseline alternative assessment studies and Environmental Impact Assessment undertaken for the soils, land capability and agricultural potential of the areas under consideration for the 30 Year Ash Disposal required by the Kendal Power Generation Plant (Power Station).

Yours sincerely
Earth Science Solutions (Pty) Ltd

Ian Jones
Director

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Declaration

This specialist report has been compiled in terms of Regulation 33.3 of the National Environmental Management Act 107/1998 (R. 385 of 2006), and forms part of the overall impact assessment for the rehabilitation and closure of infrastructure associated with the Kendal 30 Year Ash Disposal Facility Project, both as a standalone document and as supporting information to the overall impact assessment.

The specialist Pedological and Land Capability studies where managed and signed off by Ian Jones (Pr. Sci. Nat 400040/08), an Earth Scientist with 35 years of experience in this field of expertise.

I declare that both, Ian Jones, and Earth Science Solutions (Pty) Ltd, are totally independent in this process, and have no vested interest in the project.

The objectives of the study were to:

- Provide a permanent record of the present soil resources in the area that are potentially going to be affected by the proposed development – Pre development environment,
- Assess the nature of the site in relation to the overall environment and its present and proposed utilization, and determine the capability of the land in terms of agricultural potential, and
- Provide a base plan from which long-term ecological and environmental decisions can be made, impacts of development can be determined, and mitigation and rehabilitation management plans can be formulated.

The Taxonomic Soil Classification System and Chamber of Developments Land Capability Rating Systems were used as the basis for the soils, land capability and agricultural potential investigations respectively. These systems are recognized nationally.

Signed: August 2016

Ian Jones B.Sc. (Geol) Pr.Sci.Nat 400040/08
Director

GLOSSARY OF TERMS

Alluvium: Refers to detrital deposits resulting from the operation of modern streams and rivers.

Base status: A qualitative expression of base saturation. See base saturation **percentage.**

Buffer capacity: The ability of soil to resist an induced change in pH.

Calcareous: Containing calcium carbonate (calcrete).

Catena: A sequence of soils of similar age, derived from similar parent material, and occurring under similar macroclimatic conditions, but having different characteristics due to variation in relief and drainage.

Clast: An individual constituent, grain or fragment of a sediment or sedimentary rock produced by the physical disintegration of a larger rock mass.

Cohesion: The molecular force of attraction between similar substances. The capacity of sticking together. The cohesion of soil is that part of its shear strength which does not depend upon inter-particle friction. Attraction within a soil structural unit or through the whole soil in apedal soils.

Concretion: A nodule made up of concentric accretions.

Crumb: A soft, porous more or less rounded ped from one to five millimetres in diameter. See structure, soil.

Cutan: Cutans occur on the surfaces of peds or individual particles (sand grains, stones). They consist of material which is usually finer than, and that has an organisation different to the material that makes up the surface on which they occur. They originate through deposition, diffusion or stress. Synonymous with clayskin, clay film, argillan.

Desert Plain: The undulating topography outside of the major river valleys that is impacted by low rainfall (<25cm) and strong winds.

Denitrification: The biochemical reduction of nitrate or nitrite to gaseous nitrogen, either as molecular nitrogen or as an oxide of nitrogen.

Erosion: The group of processes whereby soil or rock material is loosened or dissolved and removed from any part of the earth's surface.

Fertiliser: An organic or inorganic material, natural or synthetic, which can supply one or more of the nutrient elements essential for the growth and reproduction of plants.

Fine sand: (1) A soil separate consisting of particles 0.25-0,1mm in diameter.
(2) A soil texture class (see texture) with fine sand plus very fine sand (i.e. 0.25-0,05mm in diameter) more than 30% of the sand fraction.

Fine textured soils: Soils with a texture of sandy clay, silty clay or clay.

Hardpan: massive material enriched with and strongly cemented by sesquioxides, chiefly iron oxides (known as ferricrete, diagnostic hard plinthite, ironpan, ngubane, ouklip, laterite hardpan), silica (silcrete, dorbank) or lime (diagnostic hardpan carbonate-horizon, calcrete). Ortstein hardpans are cemented by iron oxides and organic matter.

Land capability: The ability of land to meet the needs of one or more uses under defined conditions of management.

Land type: (1) A class of land with specified characteristics. (2) In South Africa it has been used as a map unit denoting land, mapable at 1:250,000 scale, over which there is a marked uniformity of climate, terrain form and soil pattern.

Land use: The use to which land is put.

Mottling: A mottled or variegated pattern of colours is common in many soil horizons. It may be the result of various processes *inter alia* hydromorphy, illuviation, biological activity, and rock weathering in freely drained conditions (i.e. saprolite). It is described by noting (i) the colour of the matrix and colour or colours of the principal mottles, and (ii) the pattern of the mottling.

The latter is given in terms of abundance (few, common 2 to 20% of the exposed surface, or many), size (fine, medium 5 to 15mm in diameter along the greatest dimension, or coarse), contrast (faint, distinct or prominent), form (circular, elongated-vesicular, or streaky) and the nature of the boundaries of the mottles (sharp, clear or diffuse); of these, abundance, size and contrast are the most important.

Nodule: Bodies of various shapes, sizes and colour that have been hardened to a greater or lesser extent by chemical compounds such as lime, sesquioxides, animal excreta and silica. These may be described in terms of kind (durinodes, gypsum, insect casts, ortstein, iron, manganese, lime, lime-silica, plinthite, salts), abundance (few, less than 20% by volume percentage; common, 20 – 50%; many, more than 50%), hardness (soft, hard meaning barely crushable between thumb and forefinger, indurated) and size (threadlike, fine, medium 2 – 5mm in diameter, coarse).

Overburden: A material which overlies another material difference in a specified respect, but mainly referred to in this document as materials overlying weathered rock.

Ped: Individual natural soil aggregate (e.g. block, prism) as contrasted with a clod produced by artificial disturbance.

Pedocutanic, Diagnostic B-horizon: The concept embraces B-horizons that have become enriched in clay, presumably by illuviation (an important pedogenic process which involves downward movement of fine materials by, and deposition from, water to give rise to cutanic character) and that have developed moderate or strong blocky structure. In the case of a red pedocutanic B-horizon, the transition to the overlying A-horizon is clear or abrupt.

Pedology: The branch of soil science that treats soils as natural phenomena, including their morphological, physical, chemical, mineralogical and biological properties, their genesis, their classification and their geographical distribution.

Slickensides: In soils, these are polished or grooved surfaces within the soil resulting from part of the soil mass sliding against adjacent material along a plane which defines the extent of the slickensides. They occur in clayey materials with a high smectite content.

Sodic soil: Soil with a low soluble salt content and a high exchangeable sodium percentage (usually EST > 15).

Swelling clay: Clay minerals such as the smectites that exhibit interlayer swelling when wetted, or clayey soils which, on account of the presence of swelling clay minerals, swell when wetted and shrink with cracking when dried. The latter are also known as heaving soils.

Texture, soil: The relative proportions of the various size separates in the soil as described by the classes of soil texture shown in the soil texture chart (see diagram on next page).
The pure sand, sand, loamy sand, sandy loam and sandy clay loam classes are further subdivided (see diagram) according to the relative percentages of the coarse, medium and fine sand subseparates.

Vertic, diagnostic A-horizon: A-horizons that have both, high clay content and a predominance of smectitic clay minerals possess the capacity to shrink and swell markedly in response to moisture changes. Such expansive materials have a characteristic appearance: structure is strongly developed, ped faces are shiny, and consistence is highly plastic when moist and sticky when wet.

1. INTRODUCTION AND PHYSIOGRAPHY

1.1 Introduction

The Kendal 30 Year Ash Disposal Project (K30ADP) has considered a number of alternatives within the vicinity of the Kendal Power Utility, with a short list of sites having been tabled from seven original sites. The shortlist included the four sites of B, C, F and H.

The rationale behind the short listing is discussed and covered in a separate document entitled "Kendal 30 Year Ash Disposal Project – Scoping Report". In this document, the desktop assessment of all of the alternatives is contemplated and the rationale behind the shortlisting of the four candidate sites is described.

The sites of interest and for which the baseline has been completed are situated to the northeast, centre and east of the Kendal Power Station, one of the operating utilities situated on the eastern Highveld of the Mpumalanga Province in South Africa (Refer to Figure 1 – Locality Plan).

The sites (B, C, F and H) comprise a total area of approximately 5,500ha of primarily cultivated or mined out land. The sites are considered "brownfield sites", the impacts of commercial farming and/or mining operations rendering these areas disturbed.

In addition, the cumulative effects of the power utility have been considered when assessing the baseline for the soils (dust fallout and the effects of dirty water on the soils) and land capability.

The effects of the existing activities and developments are clearly evident in the immediate vicinity as well as on the sites being considered, with erosion, compaction and to some degree contamination having varying degrees of impact on the soil resource and the capability of the land.

Eskom Holdings Ltd is in the process of applying for a right to expand the Ashing Facilities that it requires for the on-going operation of its power utility. This has entailed the expansion to its existing facility (the Continuous Ashing Project), in addition to the 30 Year Ashing project that will see the utility to its predicted closure. The size of the facility needed has been based on a final height of between 50m and a 100m, with a resultant footprint area of between 770ha and 520ha respectively

The process involves the conveying of the "fly ash" that is produced as a by-product and waste stream from the burning of coal and carbonaceous products in the coal fired power generating plant at Kendal Power Station to the new Ash Disposal using overland conveyers.

In addition to the actual Ash Disposal, a number of support infrastructures are required to manage and operate the facility. These include a dedicated conveyer line, access roads and servicing corridor as well as a well-engineered and dedicated water seepage and stormwater control facility.

The Ash Disposal (30 Year Facility) and associated developments (Return water dams etc.) will definitely result in a number of negative impacts to both the soils and land capability of the area and its immediate surroundings and will potentially have negative effects for the associated ecology and biodiversity that is dependent on the vadose zone and shallow soil environment.

In an attempt at quantifying the potential impacts that might result, and in order to meaningfully develop a management plan that can mitigate the effects of the planned activities it is imperative that an understanding of the pre development aspects and baseline conditions for the various alternatives are understood and documented, and that the most sustainable option is considered.

The end land use will inevitably be quite different from that mapped in the baseline study, with the Ash Disposal designed as a permanent feature that will be capped and managed as a topographic high in the present landscape. The utilisation and final land use for this feature will need to be determined as part of the final closure plan (as yet unknown/undecided), while the sustainability of the final design and utilisation plan will need to ensure that the structure is stable and free-draining. This will require a well-structured and planned construction phase, with a workable storage and stockpiling plan that will maintain the soils structural and biological conditions through the storage stage and into the rehabilitation and closure operations.

During the Scoping Phase of this project, Site C Ashing Facility was considered the best candidate site in terms of the soils and land capability assessments. However, based on the field assessments undertaken for the baseline, considerations have placed Ash Disposal Site F (F1 and F2) as the preferred site. The following in depth investigation of the four candidate sites will illustrate why the choice has changed.

It was further decided by the lead consultants in collaboration with the client that Site H was the candidate site for which additional agricultural potential studies were needed and the EI assessment completed.

Disturbance of the baseline environment will potentially result in the sterilisation of the soil resource and eco system services, with salinization and contamination of the site due to the concentration of salts and the seepage of concentrated dirty water into the underlying soils and strata.

The impacts have been assessed, and a number of management and mitigation measures tabled. These management measures are important to the long term sustainability of this development, if a stand-alone and walk away solution is to be achieved at closure.

The concept of No Net Loss (NNL) will indeed be challenged, and the possibility of Offsets will need to be considered due to the inevitable loss of resource and eco system services.

Of added importance to the earth sciences (physical environment) is an understanding of the socio economics of an area and the possible impacts that the development and its activities (transportation and deposition of a by-product and waste stream) could have on the land owners and land users that make a living or sustain themselves from the soils. This includes the effects that might be felt off site due to the erosion of soil by wind and water, and the downstream effects of sedimentary load and soil deposition.

An evaluation at a desktop level of the geomorphology of the area (topography, geology, geohydrology and hydrogeology) indicated that an investigation of all of the specialist earth sciences would be necessary if a sustainable solution was to be found for the many aspects of change that could affect the area due to a project of this nature.

These (soils and land capability), are but two of the specialist studies that have been earmarked as important to the development of the sustainability plan.

The survey intensity and coverage proposed for the soils and land capability baseline studies was tailored so as to obtain sufficient scientifically derived information that a statistically reliable information set was available, and that the information could be used for the assessment of impacts and the planning of a meaningful management plan for mitigation and the minimisation of the effects.

These studies are not intended, and must not be used for engineering designs other than the soil stripping and rehabilitation planning. Detailed geotechnical evaluations for materials sourcing and use and the strength of materials are essential for any engineering purposes.

One of the more important outcomes of the soil characterisation and classification exercise was the delineation and characterisation of the dominant soil groupings, and the rating of the soil sensitivity in terms of the activities being proposed. These aspects are considered meaningful tools and systems that can be used to identify areas that will require added inputs and or consideration in terms of legal requirements and or licensing, and will help the construction and operational teams in better managing the facility through construction and into the closure phases of the project.

In addition, and as part of understanding the sustainability equation for any new development is an appreciation for the agricultural potential of the area under consideration.

The water law and agricultural authorities require that soil wetness and the agricultural potential of the soils are assessed, with the area in question being considered an important area of food security for the Southern African region in general, and South Africa in particular (local and export markets).

The baseline has highlighted the hydromorphic soils and the shallow ferricrete based materials as areas of high sensitivity and of concern in terms of both management as well as the contribution of these areas to the biodiversity and ecological importance in the area, while the agricultural potential has been measured as a separate issue in terms of the “land capability” rating (a measure of the arable, grazing or wilderness potential of the land - Chamber of Developments – Land Capability Rating)

The proposed Ash Disposal Facility will inevitably impact on some of the hydromorphic environments identified, with much of the support infrastructure (Return water Dams and Water Control Facilities) having been planned to either traverse the wet based soils and topographic low lying areas that form the streams and water ways, or directly within these features.

These issues have been dealt with in more detail as part of the impact assessment.

The sensitive sites (predominantly shallow soils, streams, water ways and river crossings) will need to be discussed in more detail with the wetland scientist and hydrologist as part of the final design planning. Only with the inputs of the related earth sciences will a full understanding and more in-depth comprehension of these issues be obtained. This information (impact assessment) is invaluable to the development of a workable and sustainable management plan that is based on the spatial extent of the areas of concern.

All of these activities and the resultant impacts and effects will ultimately have significance to the biodiversity and ecological status of the site and surrounding areas.

This report has been compiled in line with the Guideline Document for Impact Assessment philosophy and Significance Rating System (NEMA), and ratings of impact significance have been made using the Impact rating System as required by the lead Consultants (Zitholele Consulting).

The impact assessment aims to identify and quantify the environmental and/or social aspects of the proposed activities, to assess how the activities will affect the existing state, and link the aspects to variables that have been defined in terms of the baseline study.

In addition, the impact assessment aims to define a maximum acceptable level of impact for each of the activities, inclusive of any standards, limits and/or thresholds, and assesses the impact in terms of the significance rating as defined by the lead consultants (Refer to Appendix 2). This required that the cumulative effects are considered, and that the common sources of impact are detailed.

1.2 Project Description

The project is considered a Greenfields Project in terms of the Ash Disposal that is being proposed and the associated activities that will support the project, but as a Brownfields Project due to the intensive agricultural cultivation, existing mining activities and the cumulative effects of existing power generating activities and their support infrastructure in the area.

The design plans issued as part of the ToR supplied envisage the development of a stand-alone facility as close as possible to the Power Station. The facility will require a significantly large footprint (520ha to 770ha) for the actual Ash Disposal, as well as catering for the collection and management of storm water and the conveyencing of the ash to the disposal facility.

All of these activities will impact the existing environment to a greater or lesser degree, and will be rated in terms of the site sensitivity and land capability (Refer to Figure 1 - Locality Plan).

The size of the venture is considered to be medium to large in terms of the volumes of waste that are planned for deposition, as well as being moderate to large in terms of the footprint of impact that the activities will have on the surface extent. The Life of the Operation (LoO) is estimated and planned for between 30 years and 37 years.

The final height of the facilities and the engineering design of the side slopes have been configured to minimise the size of the footprint and optimise the life of the facility. These actions will help to reduce the overall impact on the underlying resources.

The facility will be serviced by a stormwater management system (Trenches, Berms and Dams) that will contain all dirty water and separate the clean water. These facilities are part of the footprint of impact and have been considered as part of the overall effect that the proposed development might have on the physical and socio economic environments.

The existing Ashing Facility, the Kendal Power Station, the coal mining and the intensive commercial farming activities within the zone of influence of the proposed development will all have an effect on the cumulative impacts. The additional impacts from the 30 Year Ash Disposal Development will probably be confined to the site and the immediate surrounds/buffer zone if well managed, but could potentially leave the site and be transported by wind or water over larger distances if not well managed.

The geology that underlie the development site and from which the in-situ soils are derived, are typical of the South African coal fields that occur on the eastern Highveld of South Africa, and comprise for the most part horizontally bedded sediments of the Vryheid Formation of the Ecca Group (lower Permian age). An understanding of the geology has aided in the soil mapping and characterisation exercise.

The Vryheid Formation consists of alternating sandstones and shale's ranging between coarse and gritty sandstones to shale's and mudstone layers and the variations between the two extremes. These moderately old formations have been intruded and disturbed by relatively much younger intrusives that comprise dolerite sills and dykes for the most part.

Eskom Holdings SOC Ltd at their Kendal Power Utility requires additional footprint area for the deposition of the ash by product, and although they have potentially secured the extension to the exiting Disposal, this will only cater for a portion of the life expectancy of the Power Station.

The deposition of waste produced by the coal fired power station is a recognised method of managing the by-product, the premise made being that the utilisable soils will be stripped and stored as a matter of design and good practice, while the land use and its inherent capability and resultant sensitivity will be considered prior to any development decisions being made.

Impacts from the erosion of the waste by water or wind are a consideration to be included in the design decisions, while the potential for the salinisation and contamination of the soils underlying the site and those in storage are risks to be considered in the impact statement.

Added impacts include the spillage of hydrocarbons and other reagents that might be needed as part of the Ash Disposal operation, the movement of dirty water onto stored or the adjacent soils and the potential for the sterilisation and/or salinisation of these materials.

The activities associated with the deposition and storage of ash will disturb the surface features and alter the soils, land use and land capability permanently, albeit that the final disposal is planned to be shaped and covered with a soil capping that is capable of sustaining a vegetative cover under natural climatic conditions.

The end land use for this investigation and reporting has been assumed at this stage to be conservation status or possibly low intensity grazing lands.

With these assumptions as part of the rehabilitation and closure plan, it is imperative that a well-designed and sustainable soil utilisation and management plan is developed and implemented as part of the overall life of the development. The specifics of this plan will be spelled out as part of the specialist environmental management plan (EMP) for the soils and land capability.

These actions should be integral and part of the overall design philosophy.

A sustainable end use plan will need to be considered and decided on as part of the design criteria supplied, and will form the basis for the impact assessment (EIA) and management planning (EMP).

Using these well established and accepted methods of waste deposition and storage, and assuming that the lining conditions cater for the development of a barrier to infiltration of contaminants to the vadose zone and the soil layer that is left as the ash disposal footprint, the impacts to the soil environment can be limited and managed.

The use of the soils recovered from the footprint as a cover to the disposal will also assist in managing the erosion of the ash. This assumes that there will be sufficient soil material at closure, and that it has a quality that can sustain a stand-alone vegetative cover with topography that is free draining.

The permanent nature of the structures being proposed will seriously challenge the concept of No Net Loss, and the overall desire to achieve a sustainable project. Thus, an understanding of the pre development conditions is imperative, both in terms of having an accurate record of what exists now, as well as understanding the impact that an ashing facility will have, and how difficult it will be to manage and mitigate the effects.

Apart from these issues being required in terms of the law, it is important that the potential loss of an important resource (soil, land use and eco system services) needs to be understood in terms of the sustainability equation.

The soil utilisation plan will include the defining of how the mitigation will reduce the intensity and probability of the impact occurring, and what is necessary to ensure that the prescriptive mitigation proposed is clear, site specific and practical.

In addition, and as part of the practical management plan, a comprehensive monitoring system has been proposed and tabled.

The Kendal Ashing Facilities are part of the strategic development required in terms of energy production in South Africa, and although this is a proposed new development, it is part of the optimisation and extension to the life of the Kendal Power Station operation.

The lead consultants (Zitholele Consulting) contracted Earth Science Solutions (Pty) Ltd (ESS) to assist with the specialist soils and land capability sections of the baseline studies, the assessment of impacts and the development of a soil utilisation and management plan that will aid in the minimisation and mitigation for the life of the development and into the post closure (construction, operation and closure) phase.

Figure 1a shows the general location and extent of the alternatives that were considered as part of this planning, while Figures 1b, 1c 1d, 1e and 1f show the location of each of the candidate sites that were shortlisted as possible sites for the ashing facility.

Site H, chosen as the candidate site based on the weighting of all considerations has been assessed in terms of its site sensitivity, agricultural potential and land capability when considering the impact significance. These aspects were in tern used in the consideration and design of the management plan.

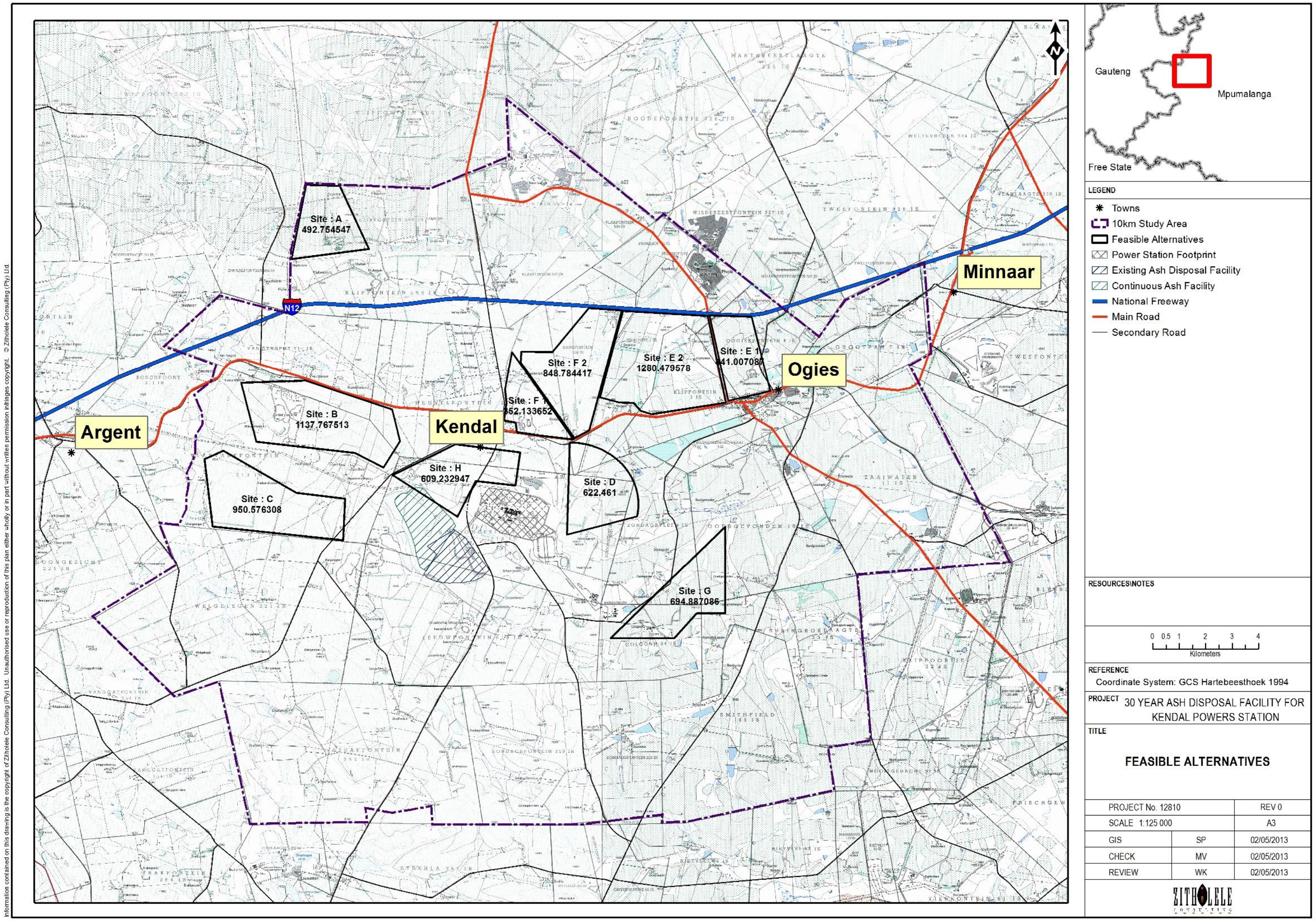

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Figure 1a – Regional Locality Plan of Site Alternatives

Figure 1b – Proposed Ash Disposal Facility – Site B

Figure 1c – Proposed Ash Disposal Facility - Site C

Figure 1d – Proposed Ash Disposal Facility – Site F1

Figure 1e – Proposed Ash Disposal Facility – Site F2

Figure 1f – Proposed Ash Disposal Facility – Site H

In line with the discussions had at the alternatives workshop, and with the results of the soil and land capability studies at hand, it was incumbent on the specialist consultants to deliver a reasoned argument for the best candidate site for the 30 Year Ashing Facility. In doing this, the earth sciences used the concept of environmental "sensitivity" or site vulnerability to assist with the rating of the various sites, the soils mapping having been simplified based on the dominant soil forms, their functionality and their associated land capability.

In this way, the sustainability of the project can be measured in terms of the impacts and related mitigation, with sensitive areas being left out completely, or managed in a sound scientifically derived manner.

The baseline findings were then used to assess and rank the impacts that can be expected on the candidate site, with the management plan for mitigation being based on the activities tabled as part of the development plan and the findings of the impact assessment.

A comprehensive soil utilization plan has also been tabled as part of the EMP and has given a functional description of how the soils should be managed if the impacts are to be minimised.

The principle or concept of "No Net Loss" (NNL) has been tabled as the ultimate aim in developing a project that is sustainable. However, the deposition of a waste product such as ash and some of the activities that are being proposed for this project will definitely challenge this concept.

The activities being proposed will definitely have a negative, but variable impact on the natural resources and they are considered to be permanent. The land use will definitely change, and the capability of the soils and the land will be altered.

1.3 Methodology and Approach

The soil and land capability specialist studies have been tailored to the site specifics of geomorphology and land use, and developed as the basis for the characterisation and classification of the soils and the rating of the land capability and determination of the agricultural potential for the candidate site.

The soil mapping is based on a specific set of principles as set down in the "Taxonomic Soil Classification, a system designed for South Africa" (described in detail later), but of relevance to many of the Southern African regions as well. These norms are consistent with the NEMA Regulations, World Bank Standards and national nomenclature.

The resultant physical and chemical characteristics of the materials are used to characterise and highlight the site specific sensitivities which are then combined into dominant soils "groupings". The groupings have similar physical and chemical characteristics that will react in a similar manner to the possible impacts predicted, and for which the same mitigation and management measures can be applied under a given set of circumstances.

This simplification of the soil forms can be used by the developer more easily and with better results as part of the planning and decision making tools (Not for design purposes). In addition, the interested and/or affected parties (Public and Authorities) can make more informed and better comment based on well-developed and scientifically based information, all of which will aid in the design of the most sustainable project.

In better understanding and informing these studies on how sensitive or vulnerable a soil is, it was essential that the system being used is able to establish and measure in a repeatable manner, the aspects and determinants that contribute to a material being robust or sensitive.

The Soil Classification System and Land Capability Rating Systems supply the scientific basis and knowledge needed to determine the sensitivity or vulnerability to the soils of the different actions and activities being proposed.

The soils physical and chemical properties and the way in which these react to the elements (wind, water erosion, heat, chemical reaction etc.), the effects of having the vegetative cover removed, or their reaction to having the topsoil disturbed, and the effects of chemical impacts (ease of being taken into solution), are all aspects that have been considered and assessed in measuring sensitivity and ultimately vulnerability to development.

These measures are important when considering the impact assessment, and will ultimately dictate the mitigation and management measures (degree of input etc.) that will be required in the management of the development.

Using this philosophy the study area was investigated on a comprehensive reconnaissance grid base, with an assessment and understanding of the pre development conditions for the soils, the land capability and agricultural potential being considered as the minimum requirements for the baseline inputs to the candidate site.

The level of study and intensity (spatial variance) of observations was guided by a number of practical variables. These included the geomorphology of the site (topography, ground roughness, attitude and climate) and knowledge of the proposed development (development plan) and the actions that are planned.

No detailed soils information was available from any of the regional assessments, and although the Land Type Maps (Government) and Geological Maps were of help in understanding the proposed planning for the area and the high level understanding of the agricultural potential, land capability and associated earth sciences variables, the sensitivities and site specific variations and aspects that are important to the ecological balance of the area were lacking.

1.4 Legal Considerations

As part of understanding the consequences of the proposed development an knowledge of the national legislation that pertains to soils and related sciences is important, and is a guide in understanding the permissible standards and limits that can be considered, albeit that there are no prescribed quantitative limits that can be quoted.

The most recent South African Environmental Legislation that needs to be considered for any new development with reference to management of soil includes:

- The Conservation of Agricultural Resources (Act 43 of 1983) states that the degradation of the agricultural potential of soil is illegal.
- The Bill of Rights (chapter 2) states that environmental rights exist primarily to ensure good health and wellbeing, and secondarily to protect the environment through reasonable legislation, ensuring the prevention of the degradation of resources.

- The Environmental right is furthered in the National Environmental Management Act (No. 107 of 1998), which prescribes three principles, namely the precautionary principle, the "polluter pays" principle and the preventive principle.
- It is stated in the above-mentioned Act that the individual/group responsible for the degradation/pollution of natural resources is required to rehabilitate the polluted source.
- Soils and land capability are protected under the National Environmental Management Act 107 of 1998, the Development Act 28 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 remedied.
- The Development Act 28 of 2002 requires an EMPR, in which the soils and land capability be described.
- The Conservation of Agriculture Resources Act 43 of 1983 requires the protection of land against soil erosion and the prevention of water logging and salinization of soils by means of suitable soil conservation works to be constructed and maintained. The utilisation of marshes, water sponges and water courses are also addressed.

In addition to the South African legal compliance this proposed development has also been assessed in terms of the International Performance Standards as detailed by the International Finance Corporation (IFC).

The IFC has developed a series of Performance Standards to assist developers and potential clients in assessing the environmental and social risks associated with a project and assisting the client in identifying and defining roles and responsibilities regarding the management of risk.

Performance Standard 1 establishes the importance of:

- Integrated assessment to identify the social and environmental impacts, risks, and opportunities of projects;
- Effective community engagement through disclosure of project-related information and consultation with local communities on matters that directly affect them; and
- The client's management of social and environmental performance throughout the life of the project.

Performance Standards 2 through 8 establish requirements to avoid, reduce, mitigate or compensate for impacts on people and the environment, and to improve conditions where appropriate. While all relevant social and environmental risks and potential impacts should be considered as part of the assessment, Performance Standards 2 through 8 describe potential social and environmental impacts that require particular attention in emerging markets. Where social or environmental impacts are anticipated, the client is required to manage them through its Social and Environmental Management System consistent with Performance Standard 1.

Of importance to this report are:

- The requirements to collect adequate baseline data;
- The requirements of an impact/risk assessment;
- The requirements of a management program;
- The requirements of a monitoring program; and most importantly;
- To apply relevant standards (either host country or other).

With regard to the application of relevant standards (either host country or other) there are no specific quantitative guidelines relating to soils and land use/capability, either locally or within the World Bank's or IFC's suite of Environmental Health and Safety Guidelines. However, the World Bank's Development and Milling, guideline does state that project sponsors are required to prepare and implement an erosion and sediment control plan.

The plan should include measures appropriate to the situation to intercept, divert, or otherwise reduce the storm water runoff from exposed soil surfaces, tailings dams, and waste rock dumps.

Project sponsors are encouraged to integrate vegetative and non-vegetative soil stabilization measures in the erosion control plan.

Sediment control structures (e.g., detention/retention basins) should be installed to treat surface runoff prior to discharge to surface water bodies. All erosion control and sediment containment facilities must receive proper maintenance during their design life.

This will be included in the appropriate management plans when they are developed at a later stage in the project's life cycle.

1.5 Assumptions, Limitations and Uncertainties

It has been assumed that the total area of possible disturbance was included in the area of study, that the development plan as tabled has documented and catered for all actions and activities that could potentially have an impact on the soils and land capability, and that the recommendations made and impact ratings tabled will be re-assessed if the development plan changes.

Limitations to the accuracy of the pedological mapping (as recognised within the pedological industry) are accepted at between 50% (reconnaissance mapping) and 80% (detailed mapping), while the degree of certainty for the soils physical and chemical (analytical data) results has been based on **"composite"** samples taken from the dominant soil types mapped in the study area.

The area in question has been mapped on a comprehensive reconnaissance base, the degree and intensity of mapping and geochemical sampling being considered and measured based on the complexity of the soils noted in field during the field mapping, and the interplay of geomorphological aspects (ground roughness, slope, aspect and geology etc.).

2. DESCRIPTION OF THE PRE-CONSTRUCTION ENVIRONMENT

2.1 Data Collection and Gap Analysis

2.1.1 Review of Available Information

The specialist pedological and land capability studies have been undertaken using a phased approach, with the desktop and scoping assessment having been completed during the middle of 2013 (28th – 30th April 2013), and the baseline investigation and alternatives assessment of the shortlisted sites being completed during September 2013 (16th to 20th September 2013) and February 2014 (15th to 18th February 2014).

The sites covered in the baseline assessment were based on the development plan made available through the lead consultants (Refer to Figure 1a to Figure 1f).

The site specific nature of the proposed development (Ash Disposal), and the spatial distribution of the support infrastructure renders the impact as local to site specific, and no alternatives can/could be considered other than the no-go option.

Site sensitivities and possible “No Go” considerations have been highlighted wherever pertinent, with specific regard being given to areas of wetness, shallow soil depths, soil erosion and compaction, with contamination a consideration due to disturbance and the effects of the development. These are the most likely aspects that will affect the loss of resource.

The site specific sensitivities have been highlighted and used in the delineation of environmentally sensitive “No Go” or “High Sensitivity” areas, and have had an impact on the alternatives assessment rating of the sites considered.

These considerations are recognised as essential in the process of sustainable development and the obtaining of scientific information that is helpful in answering the IAP’s and authorities concerns.

The construction and operation of an Ash Disposal Facility will require that new infrastructure is build and operated. This will inevitably effect the natural environment. The activities will include but are not confined to, the building and operation of a dedicated conveyer line, the excavation of stormwater trenches and the building of cut-off berms and dams, and the construction of a large lined footprint (550ha to 770ha). These activities will impact the soils and change the land capability.

Based on these planned activities, it was important that the baseline study was comprehensive enough, that it could be used by the developer for site selection actions and the development of a feasible plan

The government survey maps (geological and topocadastral) and the regional descriptions were used in obtaining an understanding of the general lithological setting for the area, while discussions with the farming community helped in understanding the possible pedogenic processes that could be unique to the specific environment. However, the scale of this information is insufficient for the level of data needed for a project of this magnitude.

Field Work

A reconnaissance pedological study of the site was performed using a comprehensive grid base, for the entire footprint area and a 300m buffer zone around the areas that are being planned for the Kendal 30 Year Ashing Facility.

The Ash Disposal footprint and all associated support infrastructure and related activities will be subjected to the removal of all utilisable soil, while the footprint associated with the deeper excavations (dams etc.) will require that all of the soil and some of the soft overburden will need to be stripped and stockpiled/stored. These actions will result in the alteration/modification of the surface topography and will permanently change the land capability and land use, while the changes in the landscape (lowering or possible rising of the land surface – bulking factor) will affect the hydrological flow patterns on surface and will potentially result in areas of "ponding" and/or erosion if they are not well managed.

Ponding of surface water and the un-managed increased in infiltration of surface water into the vadose zone will have significant negative implications for the utilisation potential and land capability. These are high negative impacts that are difficult to reverse.

Field Methodology

In addition to the grid point observations, a number of samples previously taken from the Klipspruit and Bankfontein sites were used to better understand the chemical and physical attributes of the soils in the general area. The soil mapping was undertaken using the aerial photographs supplied, and the Google Earth satellite imagery (Refer to Figure 2.1.2b, 2.1.2c, 2.1.2d and 2.1.2e– Dominant Soils) orthophotographic base. Site specific samples of the soil were taken from the candidate site.

The majority of observations used to classify the soils were made using a hand operated bucket auger and Dutch (clay) auger.

Standard mapping procedures and field equipment were used throughout the survey.

The fieldwork comprised a number of days on site during which profiles of the soil were excavated and observations made of the differing soil extremes. Relevant information relating to the climate, geology, wetlands and terrain morphology were also considered at this stage, and used in the classification of the soils of the area, while the variation in the natural vegetation was also used to help in the more accurate placing of the changes in soil form.

Terrain information, topography and any other infield data of significance was also recorded, with the objective of identifying and classifying the area in terms of:

- The soil types to be disturbed/rehabilitated;
- The soil physical and chemical properties;
- The soil depth;
- The erodibility of the soils;
- Pre-construction soil utilisation potential, and
- The soil nutrient status.

Soil Profile Identification and Description Procedure

The identification and classification of soil profiles were carried out using the *Taxonomic Soil Classification, a System for South Africa (Mac Vicar et al, 2nd edition 1991*)

The Taxonomic Soil Classification System is in essence a very simple system that employs two main categories or levels of classes, an upper level or general level containing Soil Forms, and a lower, more specific level containing Soil Families.

Each of the soil Forms in the classification is a class at the upper level, defined by a unique vertical sequence of diagnostic horizons and materials.

All soil forms are subdivided into two or more families, which have in common the properties of the Form, but are differentiated within the Form on the basis of their defined properties.

In this way, standardised soil identification and communication is allowed by use of the names and numbers given to both Form and Family.

The procedure adopted in field when classifying the soil profiles is as follows:

i. Demarcate master horizons;
ii. Identify applicable diagnostic horizons by visually noting the physical properties:

- Depth (below surface)
- Texture (Grain size, roundness etc.)
- Structure (Controlling clay types)
- Mottling (Alterations due to continued exposure to wetness)
- Visible pores (Spacing and packing of peds)
- Concretions (cohesion of development and/or peds)
- Compaction (from surface)

iii. Determined from i) and ii) the appropriate Soil Form
iv. Establishing provisionally the most likely Soil Family

Table 2.1.1 Explanation - Arrangement of Master Horizons in Soil Profile

<table>
<tr><td rowspan="11">SOLUM</td><td rowspan="11">(Zone in which the soil forming processes are maximally expressed)</td><td colspan="5">Arrangement of master horizons</td><td>Comments on Layers</td></tr>
<tr><td rowspan="10">O - Organic</td><td rowspan="5">C - Regic Sands (C), Stratified Alluvium (C), Man - Made Soil Deposits (C).</td><td rowspan="2">A</td><td rowspan="2">Humic,Vertic, Melanic, Orthic</td><td rowspan="10">G</td><td>Loose leaves and organic debris, largely undecomposed</td></tr>
<tr><td>Organic debris, partially decomposed or matted</td></tr>
<tr><td rowspan="3">B</td><td rowspan="3">Red Apedel, Yellow-brown Apedel, Soft Plinthic, Hard Plinthic, Prismacutanic, Pedocutanic, Lithocutanic, Neocutanic, Neocarbonate, Podzol, Podzol with placic pan</td><td>Dark coloured due to admixture of humified organic matter with the mineral fraction</td></tr>
<tr><td>Light coloured mineral horizon</td></tr>
<tr><td>Transitional to B but more like A than B</td></tr>
<tr><td rowspan="4">C</td><td colspan="2" rowspan="4">Dorbank, Soft Carbonate horizon, Hard Carbonate Horizon, Saprolite, Unconsolidated materials without signs of wetness, Unconsolidated materials with signs of wetness, Unspecified materials with signs of wetness</td><td>Transitional to A but more like B than A</td></tr>
<tr><td>Maximum expression of B-horizon character</td></tr>
<tr><td>Transitional to C</td></tr>
<tr><td>Unconsolidated material</td></tr>
<tr><td colspan="3">R - Hard Rock</td><td>Hard rock</td></tr>
</table>

Sample Analysis

Sampling of representative soils was carried out and submitted for analysis.

Factors that were considered in the laboratory included:

- Determination of the pH
- Exchangeable bases
- C.E.C. (cation exchange capacity)
- Texture (% clay)
- Nutrient status and
- Any potential pollutants

2.1.2 Description

Soil Characterisation

The soils encountered can be broadly categorised into four major groupings, with a number of dominant and sub dominant forms that have been combined and that characterise the area of concern (Refer to Figure 2.1.2b).

The major soil forms are closely associated with the lithologies from which the soils are derived (in-situ formation) as well as the topography and general geomorphology of the site, with the effects of slope and attitude of the land forms and the pedogenetic processes involved affecting the soil formation and ultimately the soil forms mapped.

The generally flat to slightly undulating topography has resulted in the in-situ formation of many of the soils and a moderately well-developed pedogenisis for the site, albeit that the retention of soil water within the vadose zone (lack of preferred horizontal flow) due to the horizontal bedding of the sediments and fine grained nature of the siltstone and mudstone interlayers has resulted in the creation of an inhibiting layer (calcrete/ferricrete) within some of the soil profiles.

The resultant perched water within the profile creates areas of relatively much wetter soil, a factor that is considered important to the ecology and biodiversity of the area.

It is hypothesised that, the ferricrete layer that is found associated with the horizontally bedded sediments is responsible for the restrictive layer that is holding water within the soil profile and resulting in the development of moderately extensive areas of wet based soils. This feature is inherently important to the fauna and flora and general ecology of the area.

The occurrence of extensive calcrete and/or ferricrete horizons within the soil profile classify as "relic" land forms for the most part, albeit that a significant area of more recent hard plinthite or laterite development was mapped in association with the streams and secondary rivulets in the area.

The relic land forms are commonly associated with hillside seeps and "sponge zones" (Refer to Figure 2.1.2b through 2.1.2e), both of which are associated with possible wetland development.

These ferricrete layers occasionally outcrop at surface as ouklip or hardpan ferricrete and are the basis for many of the pan structures found within the sedimentary profile and landscape of this region. These features are regarded as sensitive to highly sensitive features.

In addition, and as part of these sensitive systems, are the "transition zones" that contribute (soils within the pan catchment) to the wetland catchment systems. These areas also need to be considered as part of the sites with a status of high sensitivity. The importance of these zones cannot be over emphasised, as it is these sites and soils that act as the feeder zones to the wet based soils and wetland systems.

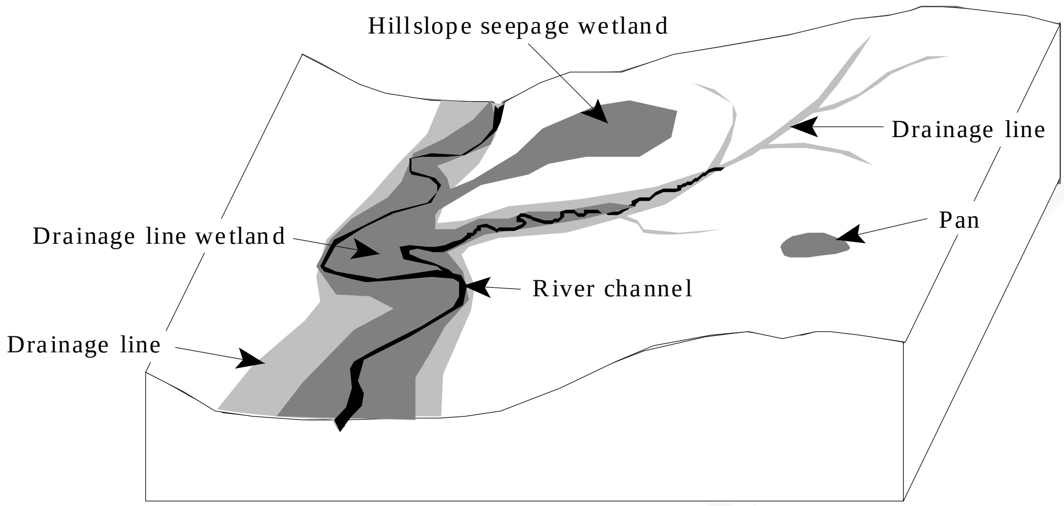

Figure 2.1.2a - Schematic of the Wet Lands and their relation to Topography.

The dominant soils classified are described in terms of their physical and chemical similarities and to some extent their topographic position and resultant pedogenisis, with their spatial distribution being of importance to the management recommendations (Refer to Figure 2.1.2b – Dominant Soils) and soil utilisation plan. The major soil groupings are described in more detail later in this section.

The soils mapped range from shallow sub-outcrop and outcrop of hard plinthite and parent materials (Sediments and intrusive dolerite) to moderately deep sandy loams and sandy clay loams, all of which are associated with either a rocky outcrop of sedimentary parent rock, or ferricrete/laterite "C" horizon at varying depths. The saprolitic horizons are generally quite thin, with soil occurring on hard bedrock in most instances mapped.

When considering the sensitivity of a wet based soil, the depth to the inhibiting layer and the amount of redox reaction present (noted in the degree of mottling and more importantly the greyness of the matrix soil) within the profile dictates the degree of wetness in terms of the "wetland delineation classification". This will have an effect on the ecological sensitivity of the site.

The shallow, to very shallow soil profiles are generally associated with an inhibiting layer at, or close to surface, and as already alluded to, is the defining feature that controls the ability (or not) of water to flow vertically down and through the profile (restrictive layer) and dictates the degree of drainage for the soil.

The degree to which the plinthite layer has been cemented (friability of the ferricrete) will determine the effectiveness of the layer as a barrier to infiltration, while the depth of overlying soil will dictate how easily or difficult it is for the soil water to be accessed by the fauna and flora, and in the extreme case weather water is held at surface as a pan.

The friability or ease of excavation (dig-ability) of the ferricrete will also have an effect on the amount of clay mineralisation that the soil contains within this horizon, and will in turn influence the water holding characteristics of the soil and the degree of structure.

In addition to the soil system of classification, a system has been developed for the describing and classification of ferricrete (Refer to Appendix 2) as well. This has been used in better understanding the land forms and the overall geomorphology of the site, and makes for a more meaningful and repeatable system of reporting the workability of the sols and underlying materials. This is important for both the construction phase, where soils need to be stripped, and the rehabilitation phase where the order of replacement is important.

In contrast, the deeper and more sandy profiles, although associated with a similar set of lithologies have distinctly differing pedogenetic processes that are associated with, better drainage characteristics, often lower clays and a deeper weathering profile. The marked difference is often the presence or lack of iron and manganese in the parent materials.

As with any natural system, the transition from one system to another is often complex with multiple facets and variations over relatively small/short distances.

In simplifying the trends mapped, the following major soil "groupings" are of importance to an understanding of the soil workability and rehabilitation potential:

- The deeper and sandier soils are considered ***High Potential*** materials and are distinguished by the better than average depth of relatively free draining soil to a greater depth (> 700mm). This group are recognisable by the subtleness of the mottling (water within the profile for less than 30% of the season), are noted at greater depths within the profile (>500mm) and the land capability is rated as moderate intensity grazing and/or arable depending on their production potential.

  These soils are generally lower in clay than the associated wet based soils and more structured colluvial derived materials, have a distinctly weaker structure and are deeper and better drained (better permeability). The ability for water to permeate through these profiles is significantly much better than for the structured and wet based soils. In addition, the more sandy texture of this soil group renders them more easily worked and they are rated as having a lower sensitivity (Deep >500mm).

- In contrast, the shallower and more structured materials are considered to be more ***sensitive*** and will require greater management if disturbed. The group of ***shallower and more sensitive soils*** (< 500mm) are associated almost exclusively with the sub outcropping of the parent materials (Karoo Sediments) (geology) at surface, and although they constitute a relatively small percentage of the overall area of study, they have a relatively large and important function in the sustainability of the overall biodiversity of the area.

- The third group of soils comprise those that are associated with the hard pan ferricrete layer and/or perched soil water. This group of soils have a set of distinctive characteristics and nature that are separated out due to their inherently much more difficult management characteristics.

  These soils are characterised by relatively much higher clay contents (sometimes of a swelling nature), poor intake rates, poor drainage, generally poor liberation of soil water and a restricted depth – often due to the inhibiting barrier within the top 700mm of the soil profile. These soils are generally associated with a ***wet base***.

  These soils will be more difficult to work in the wet state, are difficult to store and are of the more difficult soils to re-instate during rehabilitation and at closure. They are also some of the more important soils, and as such need to be identified and stripped and stockpiled separately from the dry and more sandy soils

  The groundwater levels are reported to be relatively deep (>12m) for the majority of the area of study and are reported (hydrogeologists) to have little to no influence on the soil water and water found within the vadose zone. No perched aquifers (groundwater) are reported. This would suggest that all of the hard plinthite and ferricrete noted is as a result of soil water within the vadose zone. The development of wet based soils and moist grassland environments are mapped in association with these soil forms.

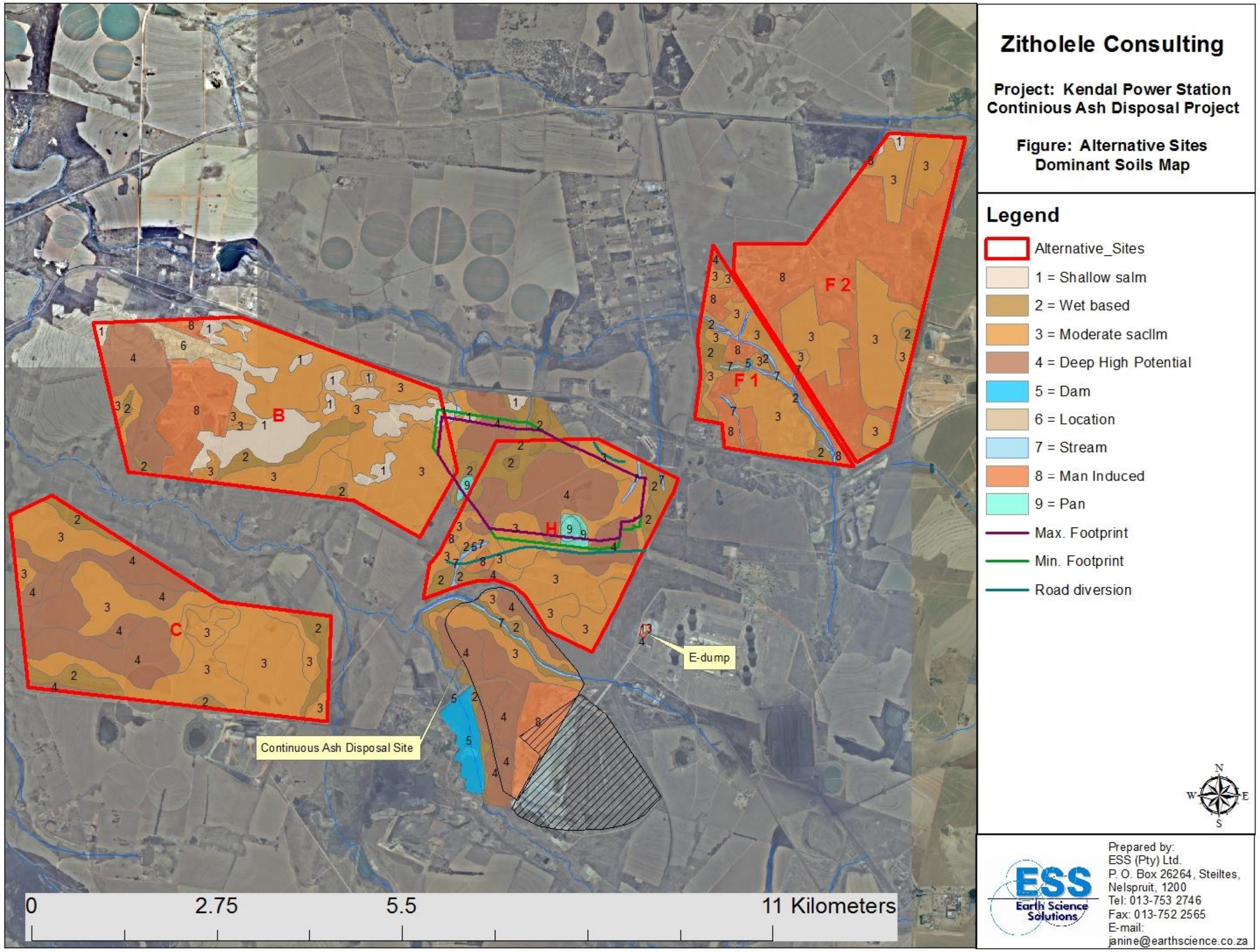

Figure 2.1.2b - Dominant Soils Map – Overall Area (All four sites)

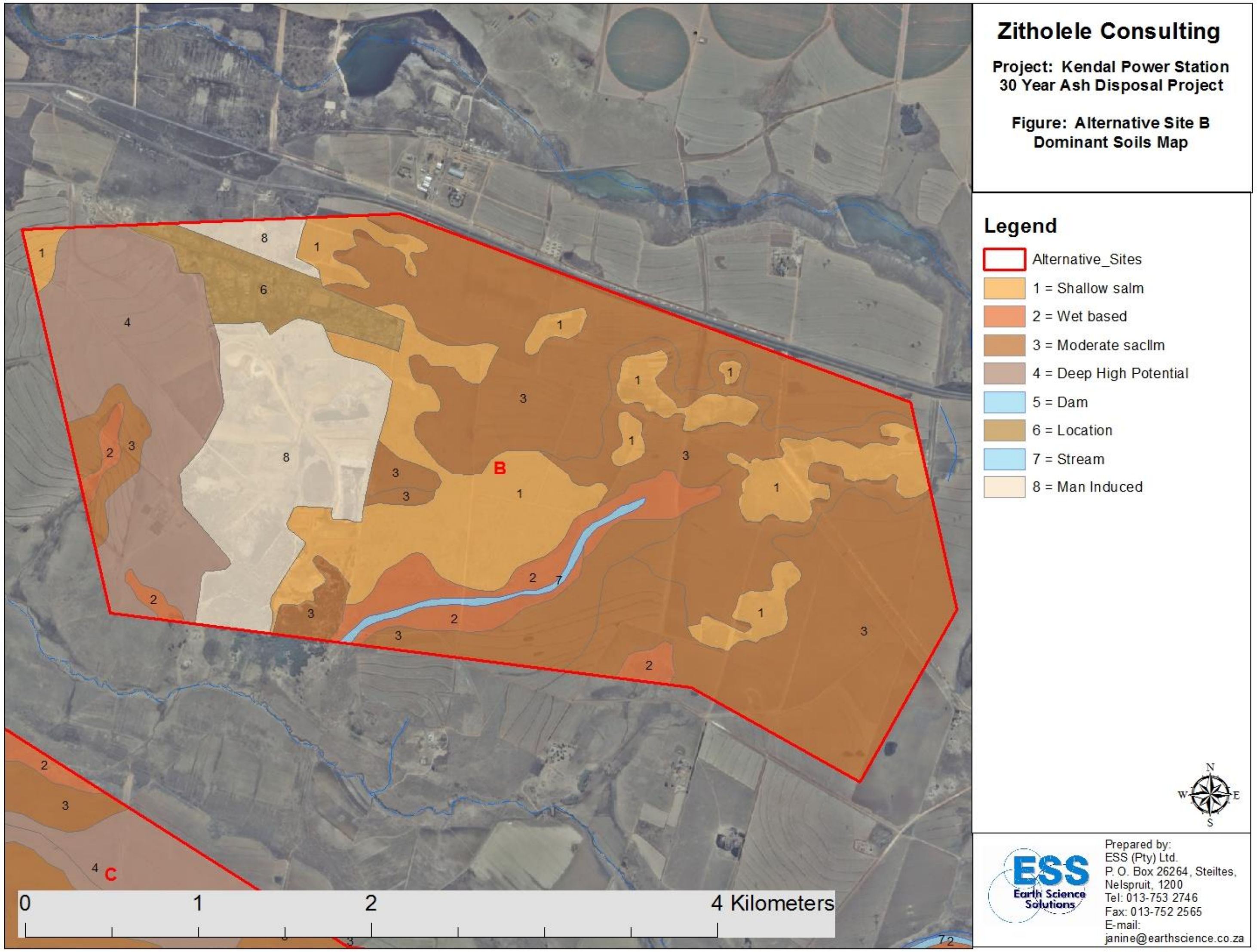

Figure 2.1.2c - Dominant Soils Map – Proposed Ash Disposal Facility Site B

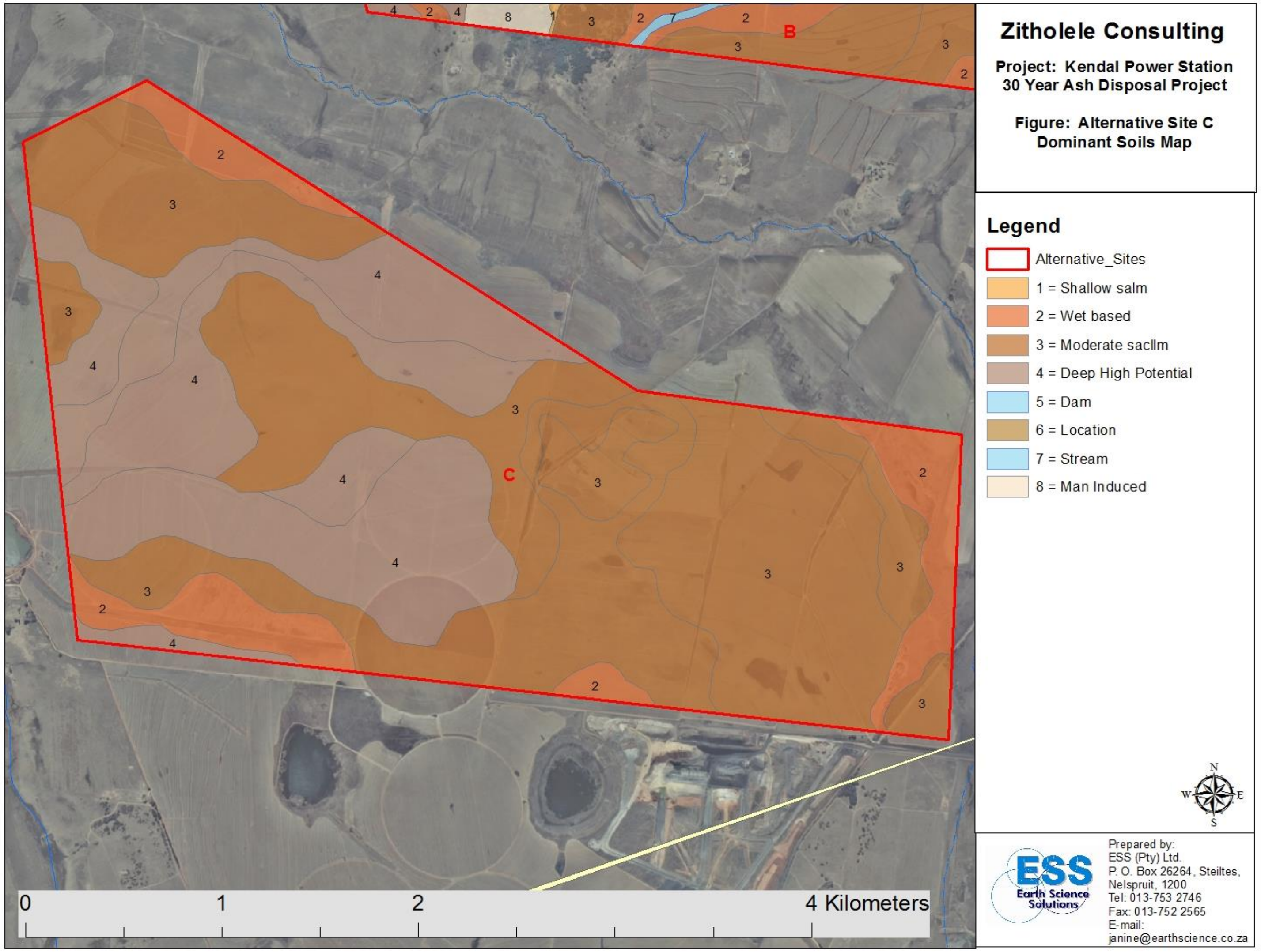

Figure 2.1.2d - Dominant Soils Map – Proposed Ash Disposal Facility Site C

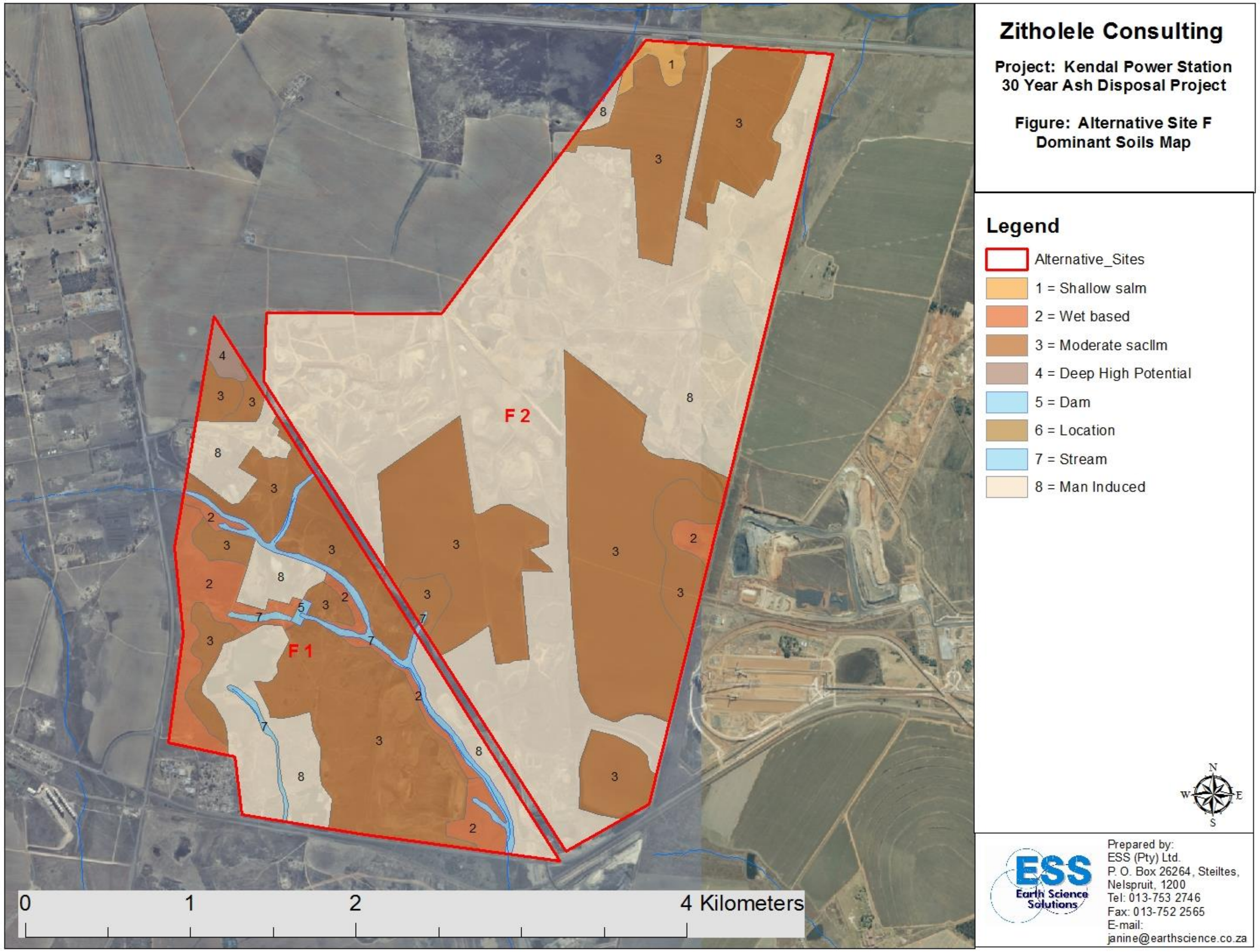

Figure 2.1.2e - Dominant Soils Map – Proposed Ash Disposal Facility Site F

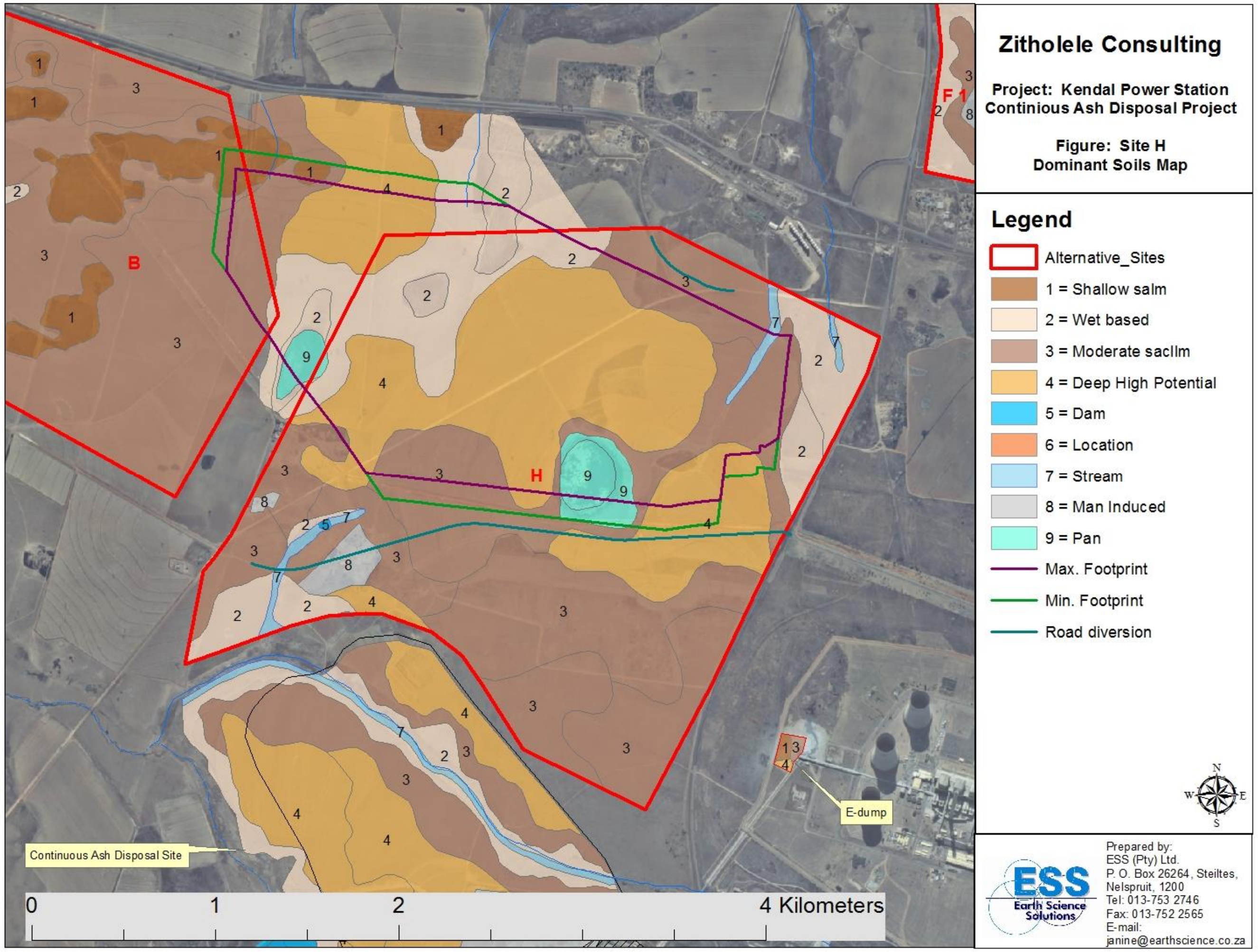

Figure 2.1.2f - Dominant Soils Map – Proposed Ash Disposal Facility Site H

Again, it is noted as important to the baseline study, that these soil groupings are moderately extensive in spatial area, and cover a moderately large and sensitive area in terms of the proposed development plan.

- In addition, but not separated from the wet based structured soils are the group of soils that reflect ***wetness*** within the top 500mm. These soils are easily recognised by the mottled red and yellow colours on low chroma background. These soils are regarded as ***highly sensitive*** zones that will require authorisation/permission if they are to be impacted. The legal implications (licensing) will need to be considered if these soils are to be impacted.

  The concentrations of natural salts and stores of nutrients within these soils are again a sensitive balance due to the extremes of rainfall, wind and temperature. The ability of a soil to retain moisture and nutrients, and in turn influence the sustainability of vegetative growth and affect the dependence of animal life is determined by the consistency and degree of soil moisture retention within the profile, and out of the influence of evaporation.

  These conditions and associated sensitivities should be noted in terms of the overall bio-diversity balance if the sustainability equation is to be managed and mitigation engineered. The shallow wet based soils are an important contributor to the ecological cycle.

All areas included in the study have been captured in a GIS format and mapped according to their soil classification nomenclature and soil depth (decimetres), while the similar soil forms have been grouped and mapped as dominant groupings for ease of management.

2.1.3 Soil Chemical and Physical Characteristics

Based on the previous investigations and environmental assessments undertaken for the area, and with a significant amount of baseline chemistry available for the site section process undertaken, the soil chemistry was obtained from existing studies of the soils on land in close proximity to the areas of concern. This information is available from soil studies that were executed during the mining right applications and as part of the MPRDA Process for coal mining projects adjacent to or on the land in question.

2.1.3.1 Soil Chemical Characteristics

The results are indicative of the pre-construction conditions and are representative of the baseline conditions only. It is important to remember that the soils will change while in storage, and the results tabled here will need to be verified for particular sites as and when rehabilitation is started.

On-going sampling and monitoring of the in-situ conditions will be necessary throughout the operational phase to accurately define the post operational conditions if the rehabilitation is to be successful.

The results of the laboratory analysis returned a variety of materials that range from very well sorted sandy loams with lower than average nutrient stores and moderate clay percentages (<20% - B2/1), to soils with a moderately stratified to weak blocky structure, sandy loam to clay loam texture and varying degrees of utilizable, while the nutrient stores on the colluvial derived materials, and the extremes of much higher clay and stronger structure that are noted on the wet based and wetland soils, returned lower than average nutrient concentrations and better than average water holding capabilities.

In general, the pH ranges from acid at 5.8 to neutral and slightly alkaline at 7.5, a base status ranging from 5.2me% to 22.8me% [Mesotrophic (moderate leaching status) to Dystrophic (Highly leached)], and nutrient levels reflecting generally acceptable levels of calcium and magnesium, but deficiencies in the levels of potassium, phosphorous, and zinc. The organic carbon matter is reflective of the semi-arid environment.

The more structured (moderate blocky) and associated sandy and silty clay loams returned values that are indicative of the more iron rich materials and more basic lithologies that have contributed to the soils mapped. They are inherently low in potassium reserves, and returned lower levels of zinc and phosphorous.

The growth potential on soils with these nutrient characteristics is at best moderate to poor and additions of nutrient and compost are necessary if commercial returns are to be achieved from these soils. They are at best moderate to good grazing lands.

Table 2.1.3.1 Analytical Results

Sample No.	**CA1**	**CA2**	**CA3**	**CA4**	**CA5**	**CA6**	**CA8**	**EEP15**	**EEP19**	**ED1**	**ED2**	Optimum Range
Soil Form	**Cv**	**Av**	**Gc**	**Pn**	**Ka**	**Hu**	**Kd**	**Sd/Hu**	**Rg**	**Dr**	**We**	
Constituents mg/kg												
pH	6.25	6	5.5	6.5	5.2	6.4	6.4	6	5.5	6.1	6.4	5.2 - 6.5
"S" Value	11.2	8.9	22.1	14.8	31	11	22	22.8	33	5.2	5.8	
Ca Ratio	59	70	66	65	62	65	49	68	62	70	65	55-75
Mg Ratio	16	24	30	32	34	22	28	34	34	28	10	18-30
K Ratio	18	4	1	1	7	4	8	4	9	0.6	12	6-10
Na Ratio	0.2	0.3	0.2	1.6	1.1	0.5	0.3	0.4	0.8	1.4	0.2	
P	111	22	8	6	17	10	15	12	20	5	82	20 -80
Zn	7.2	2	1	1.1	1.4	1.5	1.4	2	1.1	1	1.6	2-10
Sand	45	42	34	46	18	52	21	42	16	58	44	
Silt	39	36	38	46	22	30	27	26	26	34	35	
Clay	16	22	28	8	60	18	52	32	58	8	21	15 -25
Organic Carbon %	0.15	0.32	0.45	0.12	0.75	0.45	0.6	0.8	0.2	0.15	0.2	>0.75

Soil fertility

The soils mapped returned at best moderate levels of some of the essential nutrients required for plant growth with sufficient stores of calcium and magnesium. However, levels of Na, Zn, P, and K are generally lower than the optimum required. These conditions are important in better understanding the land capability ratings that are recorded, with the majority of the study area being rated as low intensity grazing land.

These poor conditions for growth were further compounded by the low organic carbon (< 0.75%).

There are no indications of any toxic elements that are likely to limit natural plant growth in the soils mapped within the study area

Nutrient Storage and Cation Exchange Capacity (CEC)

The potential for a soil to retain and supply nutrients can be assessed by measuring the cation exchange capacity (CEC or "S" Values) of the soils.

The inherently low organic carbon content is detrimental to the exchange mechanisms, as it is these elements which naturally provide exchange sites that serve as nutrient stores.

The moderate clay contents will temper this situation somewhat with at best a moderate to low retention and supply of nutrients for plant growth.

Low CEC values are an indication of soils lacking organic matter and clay minerals. Typically a soil rich in humus will have a CEC of 300 me/100g (>30 me/%), while a soil low in organic matter and clay may have a CEC of 1 me/100g to 5 me/100g (<5 me/%).

Generally, the CEC values for the soils mapped in the area are moderate.

Soil organic matter

The soils mapped are generally low in organic carbon. This factor coupled with the moderate to high clay contents for the majority of the soils mapped will adversely affect the erosion indices for the soils.

2.1.3.2 Soil Physical Characteristics

The majority of the soils mapped exhibit apedal to weak crumby structure, low to moderate clay content and a dystrophic leaching status. The texture comprises sandy to silty sands for the most part, with much finer silty loams and clay loams associated with the colluvial and alluvial derived materials associated with the lower slope and bottom land stream and river environs respectively.

Of significance to this study, and a feature that is moderately common across the three sites where the soils are associated with the sedimentary host rocks (albeit that it often occurs below the 1.5m auger depth on the deeper soils) is the presence of a soft plinthic or hard pan ferricrete (plinthite) layer within the soil profile.

The semi-arid climate (negative water balance) combined with the geochemistry of the host rock geology are conducive to the formation of evaporites, with the development of ferruginous layers or zones within the vadose zone. The accumulation of concentrations of iron and manganese rich fluids in solution will result in the precipitation of the salts and metals due to high evaporation (negative water balance). This process results in the development of a restrictive or inhibiting layer/zone within the profile over time.

The negative water balance is evidenced by the generally low rainfall of 800mm/year or less, and the high evaporation that averages 1,350mm/year. These are the driving mechanisms behind the ouklip or hard pan ferricrete mapped.

The degree of hardness of the evaporite is gradational, with soft plinthic horizons (very friable and easily *dug with a spade or shovel),* through hard plinthite soil *(varying in particle size from sand to gravel – but no cementation)* to nodular and hard pan ferricrete or hard plinthic *(cementation of iron and manganese into nodules)* that are not possible to free dig or brake with a shovel.

This classification is taken from - Petrological and Geochemical Classification of Laterites -*Yves Tardy, Jean-Lou, Novikoff and Claude Roquid,* and forms the basis for classify the hard pan ferricrete or lateritic portion of the soil horizon in terms of its workability (engineering properties) and storage sensitivities.

The soil classification system takes cognisance of ferricrete and has specific nomenclature for these occurrences (Refer to The South African Taxonomic Soil Classification – See list of references).

The variation in the consistency of the evaporite layer, its thickness and extent of influence across/under the site are all important to the concept of a restrictive horizon or barrier layer that is formed at the base of the soil profile and/or close to the soil surface.

Where this horizon develops to a nodular form or harder (Nodular, Honeycomb and Hard Pan) the movement of water within the soil profile is restrict from vertical movement and is forced to move laterally or perch within the profile. It is this accumulation of soil water and the precipitation of the metals from the metal and salt rich water that adds progressively to the ferricrete layer over time.

Important to an understanding of the development of the ferricrete is the geological time and presence of the specific soil and water chemistry under which the horizon forms. This situation will be very difficult to emulate or recreate if impacted or destroyed.

2.1.4 Soil Erosion and Compaction

Erodibility is defined as the vulnerability or susceptibility of a soil to erosion. It is a function of both the physical characteristics of a particular soil as well as the treatment of the soil.

The resistance to, or ease of erosion of a soil is expressed by an erodibility factor ("K"), which is determined from soil texture/clay content, permeability, organic matter content and soil structure. The Soil Erodibility Nomograph (*Wischmeier et al,* 1971) was used to calculate the "K" value.

With the "K" value in hand, the index of erosion (I.O.E.) for a soil can then be determined by multiplying the "K" value by the "slope" measured as a percentage. Erosion problems may be experienced when the Index of Erosion (I.O.E) is greater than 2.

The majority of the soils mapped can be classified as having a moderate to high erodible erodibility index in terms of their organic carbon content and clay content, albeit that this rating is off-set and tempered to a rating of moderate or low by the undulating to flat terrain.

However, the vulnerability of the "B" horizon to erosion once the topsoil and/or vegetation is removed must not be under estimated when working with or on these soils. These horizons (B2/1) are vulnerable and rate as medium to high when exposed.

The concerns around erosion and inter alia compaction, are directly related to the disturbance of the protective vegetation cover and topsoil that will be disturbed during any construction and operational phases of the development venture. Once disturbed, the effects and actions of wind and water are increased.

Loss of soil (topsoil and subsoil) is extremely costly to any operation, and is generally only evident at closure or when rehabilitation operations are compromised.

Well planned management actions during the planning, construction and operational phases will save time and money in the long run, and will have an impact on the ability to successfully "close" an operation once completed.

2.2 Pre-Construction Land Capability

2.2.1 Data Collection

Based on a well-developed and scientifically founded baseline of information, the South African Chamber of Developments (1991) Land Capability Rating System in conjunction with the Canadian Land Inventory System has been used as the basis for the land capability study.

Using these systems, the land capability of the study area was classified into four distinctly different and recognisable classes, namely, wet land or lands with wet based soils, arable land, grazing land and wilderness or conservation land. The criteria for this classification are set out in Table 2.2.1.

Table 2.2.1 Criteria for Pre-Construction Land Capability (S.A. Chamber of Developments 1991)

Criteria for Wetland

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

Criteria for Arable Land

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

Criteria for Grazing Land

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

Criteria for Conservation of Land

Land, which does not qualify as having wetland soils, arable land or grazing land, and as a result is regarded as requiring conservation practise/actions.

2.2.2 Description

The "land capability classification" as described above was used to characterise and classify the soil polygons or units of land identified during the pedological survey.

These combined with the geomorphological aspects (ground roughness, topography, climate etc.) of the site were then employed to rate the capability of the land in question.

The area to be disturbed by the proposed ash deposition and its surface infrastructure development comprises a range of land capability classes, with significant areas of friable and good grazing potential class soil, smaller areas or good arable potential materials and significant areas associated with the lower lying areas topographically of highly sensitive sites that returned wet based soils. The colluvial derived soils are at best considered to have a low intensity grazing land potential or wilderness status.

Figure 2.2.2a through 2.2.2e illustrates the distribution of land capability classes across the study areas.

Arable Land

The arable potential for the majority of the soils mapped is low unless substantial quantities of fertiliser and manure are added. Some soil depths are reflective of a arable status (>750mm), however, the growth potential (nutrient status and soil water capabilities) and ability of these soils to return a cropping yield equal to or better than the national average is lacking. This is due mainly to the poor rainfall and less than optimum nutrient status of many of the soils. These variables reflect the natural conditions, and do not include any man induced additives such as fertilizers or water.

Grazing Land

The classification of grazing land is generally confined to the shallower and transitional zones that are well drained. These soils are generally darker in colour, and are not always free draining to a depth of 750mm but are capable of sustaining palatable plant species on a sustainable basis (only the subsoil's at a depth of >500mm are periodically wetted). In addition, there should be no rocks or pedocrete fragments in the upper horizons of this soil group. If present it will limit the land capability to wilderness land.

The majority of the study area classifies as low intensity grazing land or wilderness status.

Wilderness / Conservation Land

The shallow rocky areas and soils with a structure stronger than strong blocky (vertic etc.) are characteristically poorly rooted and support at best very low intensity grazing, or more realistically are of a Wilderness character and rating.

Wetland (Areas with wetland status soils)

Wetland areas in this document (soils and land capability) are defined in terms of the wetland delineation guidelines, which use both soil characteristics, the topography as well as floral and faunal criteria to define the domain limits (Separate Wetland Delineation has been undertaken). Only the soils are described here.

These zones (wetlands) are dominated by hydromorphic soils (wet based) that often show signs of structure, and have plant life (vegetation) that is associated with seasonal wetting or permanent wetting of the soil profile (separate study).

The wetland soils are generally characterised by dark grey to black (organic carbon) in the topsoil horizons and are often high in transported clays and show variegated signs of mottling on gleyed backgrounds (pale grey colours) in the subsoil's. Wetland soils occur within the zone of soil water influence.

A significant but relatively small proportion of the study area classifies as having wet based soils. However, it is important to note that a significantly large area of the open pit and infrastructure development being planned encroaches on soils with a wet base.

These should not be mistaken as wetlands in terms of the delineation document, but should be highlighted as potential zones of sensitivity with the potential for highly sensitive areas associated with the prominent waterway associated with the development area.

These zones are considered very important, highly sensitive and vulnerable due to their ability to contain and hold water for periods through the summers and into the dry winter seasons.

2.3 Agricultural Potential Assessment

2.3.1 Background Information and System

The candidate site (Site H) was highlighted in the soil and land capability studies as an area of interest based on the spatial extent and distribution of deep well drained soils, and the land use noted in the form of significant areas of irrigated land (Centre Pivot Irrigation).

In assessing the merits of the area delineated for development it was considered prudent that the agricultural potential was understood and documented as part of the baseline of information. Food security and an understanding of the eco system services that could be impacted and/or lost are issues that need to be captured as part of the significance rating.

The system employed included a more detailed assessment of the geomorphology of the site and the collection of more scientific data from laboratory analysis. This information has been used to assess and rate the “Agricultural Potential” (AP) of the area using the Agricultural Suitability Rating (ASR) System as tabled below (Table 2.3a).

The additional scientific information obtained from the analytical analysis detailed the physical and chemical variations of the soils, while topographic and ground roughness were noted in conjunction with any geological changes as part of the geomorphological characterisation. These aspects were mapped as dominant soils (Refer to Figure 2.3.2a), while the Agricultural Potential is depicted in Figure 2.3.3.

Ideally, soils used for economic agricultural production should satisfy the following conditions:

- Moderate uniformity
- Good rooting depth (>700mm)
- Low rockiness hazard (<20%)
- Moderate permeability
- Good supply of available moisture (T.A.M.C. >70mm/m)
- Satisfactory aeration and infiltration rates (>8mm/hr)
- Moderate resistance to erosion
- Salinity and exchangeable sodium levels should be less than 200 milli-Siemens per meter (mS/m) and 2 milli-equivalents per hundred grams (me/100g).

Applying these criteria where possible to the soils that were mapped, a scale of Agricultural Suitability (AS) based on the limitations of the above factors has been defined for the varying soil groups, thus assisting in the determination of the agricultural potential of the site. The system used is shown Table 2.3a below, while the analytical results for the additional soil samples assessed are tabled in Table 2.3b.

The ASR was included as part of the overall baseline of information that has been used in the Impact Assessment and determination of the management measures.

It is considered pertinent that this variable (Agricultural Potential) is better understood in terms of both the eco system services that will be lost as well as the mitigation that needs to be considered.

Table 2.3a: Suitability Ratings

Suitability Unit	Rating No.	Soil depth & Soil Forms	Degree of Limitation	Management Needs
AO; BO	Very good (1)	>10Hu, Cv, Gf	None	Very good irrigation
BO; A1; B3:4	Good (2)	>8Hu, Cv, Sd, Gf, Oa	Slight Moist Limit Slight Erosion Hazard.	Good Irrigation Soils Good Conservation
A2; B1, B2; B3:4; CO:2	Moderate (3)	>6Hu, Cv, Gf, Oa, Sd, Pn, Va, Se	Moderate depth Low T.A.M.C. Erosion Hazard = Moderate	Irrigation. Small amounts of water more frequent
C2: D1x1: D1x:4, D2;3	Poor (4)	<600 but >400mm of any soil form	Severe, depth erosion, with signs of wetness	Not good. Unsuitable to Irrigation Dryland Pastures
D2; C1 x D3: 4E	Unsuitable (5)	All wet and very shallow soils	Very severe depth limit, wetness and erosion	Dryland Pastures Not Recommended for Irrigation

Highlighted area = excluded from irrigation development

Suitability Grades

A - Excellent	0 - No major limitations
B – Good	1 - Slight salinity or water logging hazard
C – Fair	1x - Marked salinity or water logging
D – Poor	2 - Shallow soil depth
E - Unsuitable	3 - Surface capping / rusting
	4 - Severe erosion hazard

The ratings vary from very good to unsuitable as the degree of limitation progressively becomes more severe.

Table 2.3b: Analytical Results – Soils

SOIL STANDARD ANALYSIS

Sample No	pH(water)	Res(ohms)	Ca mg/kg	Mg mg/kg	K mg/kg	Na mg/kg	P (Bray1)	Al mg/kg	Ca/Mg	Ca+Mg/K	CEC cmol(-)/kg
482	5.05	2200	286	87	204	6	6.5	25	3.29	1.83	2.97
487	5.02	1800	425	74	89	55	13.8	30	5.74	5.61	3.53
490	4.87	2000	204	52	65	7	9.1	59	3.92	3.94	2.30
491	6.27	3500	409	70	54	3	41.6	11	5.84	8.87	2.89
492	5.38	2100	273	58	58	5	40.0	23	4.71	5.71	2.27
495	5.76	400	513	120	412	193	26.9	13	4.28	1.54	5.59
496	5.84	1500	506	105	186	19	24.5	17	4.82	3.29	4.14
500	6.13	2500	507	86	55	16	18.4	7	5.90	10.78	3.53
509	5.62	2000	407	112	74	28	5.1	9	3.63	7.01	3.36
516	6.28	1400	748	130	141	24	54.3	9	5.75	6.23	5.37
520	6.11	1900	316	84	68	11	10.7	10	3.76	5.88	2.60
524	4.64	1700	282	53	99	8	22.7	45	5.32	3.38	2.63

Sample No	Zn mg/kg	Fe mg/kg	C %	Org Mat %	Sand %	Silt %	Clay %
482	8.70	86.4	0.98	1.68	78	7	15
487	3.69	303.1	0.9	1.65	76	7	17
490	5.56	74.1	0.59	1.01	80	7	13
491	14.64	64.2	0.47	0.80	82	5	13
492	2.87	88.5	0.31	0.54	82	5	13
495	6.30	76.4	0.66	1.14	80	3	17
496	42.99	90.5	1.17	2.01	68	9	23
500	2.24	71.2	0.85	1.45	86	3	11
509	2.77	75.2	0.66	1.14	74	7	19
516	9.15	88.3	0.95	1.68	74	7	19
520	3.87	154.1	0.65	1.14	78	5	17
524	3.16	79.4	0.55	0.98	74	9	17

2.3.2 Soil Descriptions

In the course of the soil survey a number of differing soil forms were mapped. These included:

Clovelly (Cv), Hutton (Hu), Glencoe (Gc), Dresden (Dr) and Glenrosa (Gs), so well as the more hydromorphic Forms, namely Avalon (Av), Westleigh (We) and Pinedene (Pn).

The distribution of the dominant soils mapped/classified is shown graphically below in Figure 2.3.2a and the Agricultural Potential in Figure 2.3.3.

The dominant soil mapped and classified have been described below in more detail, with consideration of the soil physical and chemical properties and the overall geomorphology (climate, topography, ground roughness and geology) being included in better understanding the agricultural potential and spatial distribution across the area of study.

Hutton (Hu) and Clovelly (Cv)

The Hutton and Clovelly soil Forms returned results that have an average rooting depth (ERD) of between 400mm and 1,200mm on average, generally have a fine to medium grained texture and sand fraction, and in the majority of cases mapped they exhibit structure that is apedal to single grained.

These soils are generally confined to the middle and lower-mid slope positions adjacent to and up slope of the Avalon and Pinedene Forms.

The physical characteristics of these soils are fairly well drained. Overall they returned moderate to high intake rates (10 to 13mm/hr), coupled with moderate to low TAM, ranging from 36mm/m on the shallower sandy soils to over 95mm/m on the heavier deeper soils, have moderate to good internal drainage and moderate to high compactability.

With these characteristics the soils can be described as moderate to good on the Agricultural Suitability Rating (A.S.R.) scale namely B-0 to A-1 and are of the better agricultural soils mapped in the area. Restrictions at depth to drainage are evident in some of the profiles mapped at the B/C interface, often on what appears to be a hard plinthic or saprolitic layer. Erosion is generally not a major problem, but needs to be monitored with respect to the relief of the site, and will definitely increase in severity (increase in the erosion index) if the vegetative cover is disturbed or removed.

Chemically, these soils returned lower than average amounts of the essential nutrients needed for adequate growth regimes, albeit that the Ca/Mg ratio is good, and the levels of Zinc (Zn), iron (Fe) and Aluminium (Al) are adequate. The pH readings of between 4.6 and 6.2 render these soils acid in character.

RECOMMENDATION: Suitable for most agricultural development if sufficient water is made available. Good irrigation/water management would be needed if these lands were to be considered for irrigated pastures or economic dryland cultivation. The depth of rooting is considered moderate to good in terms of commercial agricultural.

Mispah (Ms) and Glenrosa (Gs)

The Mispah and Glenrosa soil Forms returned effective rooting depths (ERD) of between 100mm and 400mm. The major hazards encountered with these soil types is erosion and loss of the eco system services due to the shallow ERD, the poor vegetative cover and the rockiness of some of the areas.

A layer of trash or grass should be left covering the surface and the minimum tillage system should be employed if these soils are to be cultivated. Tillage constraints are moderate due to machine wear and subsurface hindrance (rocks etc. in the profile).

Geophysical, the soils returned moderate clay percentages (12 25%), moderate intake rates (6 to 10mm/hr), low available moisture holding capacities (<40mm/m) and better than average drainage.

RECOMMENDATION: Unsuitable for any commercial agriculture due to the shallow and/or varying soil depth.

Glencoe (Gc) and Dresden (Dr)

The Glencoe and Dresden (Dr) soil Forms are associated with the more iron rich lithologies and sites with impaired drainage, the underlying ferruginous/hard pan ferricrete layer forming a barrier to the vertical movement of soil water.

These soils are considered sensitive to disturbance, with the storage of soil water within the vadose zone considered a positive contributor to the biodiversity and ecological functioning of the environment.

These soils are often associate with historical land surfaces in the region, particularly where they are derived from horizontally bedded sediments.

These soils returned poor intake rates (2 to 4mm/hr), have a low available moisture holding capability, are low in available nutrients and are considered sensitive to the removal of vegetative cover and topsoil disturbance with resultant increases in the erosion index if they are not well managed. These soil forms classify as “transitional” soils under the wetland delineation system where the hard plinthite is below 500mm and as wetland soils on shallow soils of 500mm and less.

Detailed sampling is recommended if they are to be planted and a high degree of irrigation management would be needed if they are to be considered for irrigated cropping.

RECOMMENDATION: Poor to Unsuitable Agricultural Potential Lands.

Cultivation for dryland grazing at best. Under irrigation these soils become wetter for prolonged periods, increase the level of vadose water and resulting in waterlogged conditions. These are of the more sensitive materials mapped and are considered of the poorer agricultural sites.

Pinedene (Pn), Avalon (Av) and Westleigh (We)

The Avalon and Pinedene soil Forms are associated with the lower lying areas and midslope seeps that are often associated with a change in the local geology, and where vertical flow of water within the vadose zone has been impeded.

These soils returned moderate to poor intake rates (4 to 8mm/hr), have a lower than average moisture holding capability, are generally moderate to poorly drained, especially in lower horizons and are prone to erosion on the steeper slopes.

On average, these soils tend to be low in available nutrients and a mesotrophic to dystrophic leaching status.

RECOMMENDATION: Poor to Unsuitable Agricultural Potential Land.

These soils are unsuitable for cultivation. Under irrigation these soils become wetter for prolonged periods resulting in waterlogged conditions.

2.3.3 Total Available Moisture Capability (T.A.M.C.)

The soil study and the resulting T.A.M.C.’s as measured, are confined to selected auger sites, while the chemistry has been assessed based on a suite of composite samples representative of the most dominant soils in the study area.

The outcomes are summarised in Table 2.3.3 below

Table 2.3.3: Total Available Moisture

Soil Name	Soil Code	Soil Depth (mm)	Water Holding capability (mm/m)	ERD (m)	% Intake	Agricultural Suitability Rating	Irrigation Suitability	ISR
Avalon	Av	400~600	58	0.6	80	Moderate	Fair / Good	C-2
Clovelly	Cv	600~900	75	0.7	90	Moderate to Good	Good	B-2
Clovelly	Cv	400~600	48	0.6	60	Moderate	Fair	A-1
Glencoe	Gc	400~600	55	0.6	65	Moderate	Fair	B-0
Glencoe	Gc	200~400	42	0.4	40	Moderate to Poor	Fair	C 1x
Glencoe/Clovelly	Gc/Cv	600~800	68	0.7	80	Moderate to Good	Good	B-1
Glenrosa	Gs	200~400	38	0.4	50	Poor/Unsuitable	Fair	C-2
Glenrosa/Clovelly	Gs/Cv	200~400	36	0.4	65	Moderate to Poor	Fair	C-2
Westleigh	We	200~400	60	0.4	45	Unsuitable	Poor	E1x
Mispah	Ms	0~200	32	0.2	50	Unsuitable	Poor	E1x
Hutton	Hu	700~1200	85	1.0	110	Good	Good	B0/A0
TOTAL								

A.S.R. Explanation

A	Very high potential, well suited to irrigation	**0**	No major limitations
B	Generally well suited with high potential under irrigation	**1**	Slight salinity of water
C	Not as well suited owing to soil depth, drainage limitations – have a fair to moderate potential under drip irrigation.	**2**	Shallow soil depth
D	Generally not recommended, as soil limitations such as depth, drainage and or moisture retention may be severe – exceptionally good management is required if to be planted.	**3**	Surface crusting/capping
E	Should be avoided completely.	**4**	Severe erosion hazard

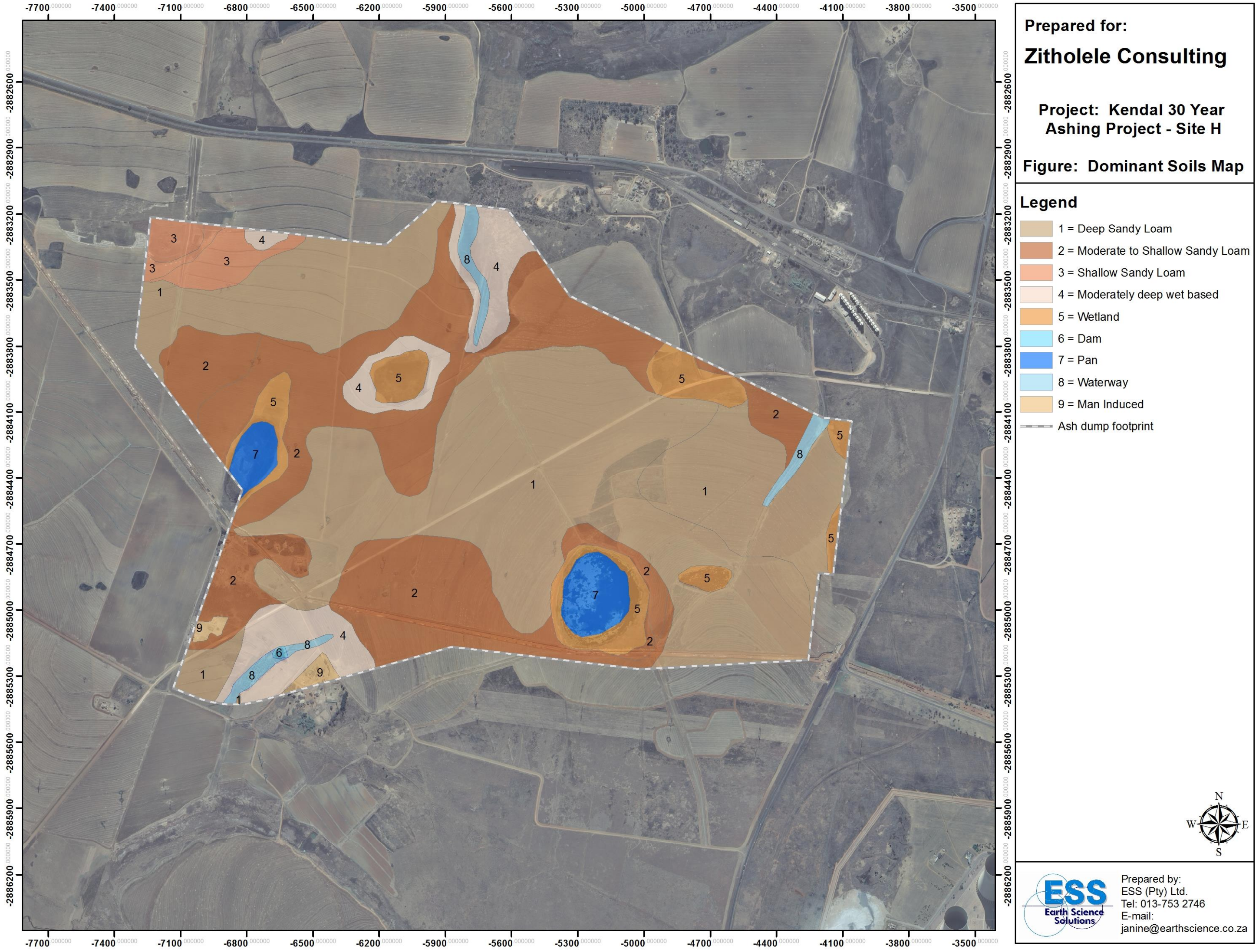

Figure 2.3.2a – Dominant Soils – Site H

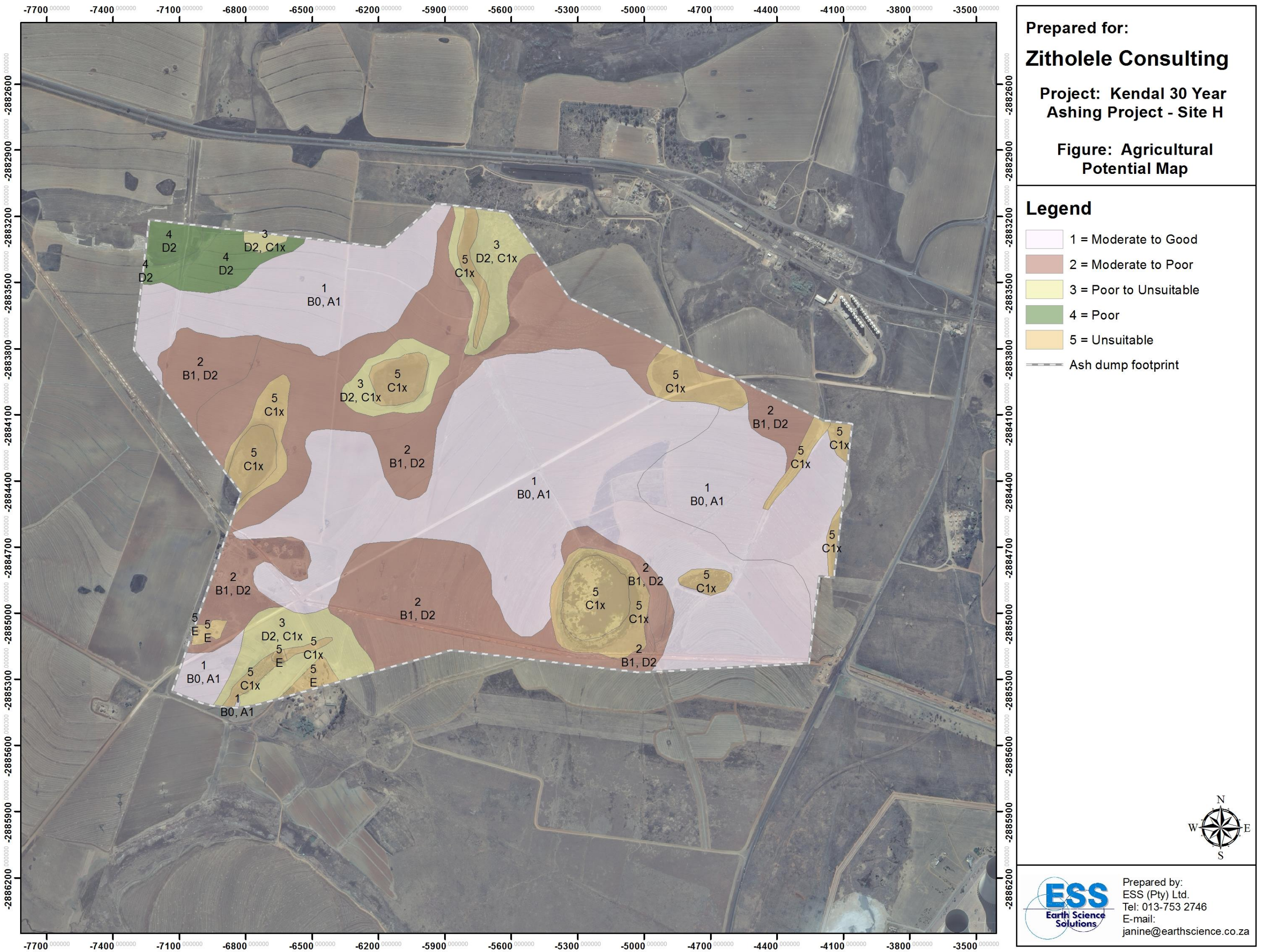

Figure 2.3.3a – Agricultural Potential Map

2.3.4 Conclusions

The foregoing chapters have focussed on aspects such as soil survey procedure, soil classification and mapping, and a description and classification of the soils in the area. In line with environmental considerations and best practise guidelines it is important that the lands capability is well understood before any development is considered for an area, with the agricultural potential a facet that speaks directly to the eco system services as well as the socio-economics of the environmental significance, and in turn the sustainability of a project,

Using the Agricultural Suitability Rating (A.S.R) as a measureable management variable, a value could be assigned to the agricultural potential for the area of concern. In determining the agricultural potential, the site has been rated on criteria such as unrestricted rooting depth (at least 700mm), a good supply of available water in the rooting zone (at least 700mm/m), satisfactory aeration and infiltration rate, no extremes of texture, low rockiness content and low levels of sodicity and salinity.

The Kendal 30 Year Ashing Project and Site H in particular is considered to be an important initiative for the area in terms of the power generation industry.

The Agricultural Potential of the land is however a concern in terms of the eco system services and security of food production for the country, and the socio economic aspects around job security and the sustainable utilisation of land.

Sites with an agricultural potential greater than “moderate” (Refer Table 2.3.4) are considered to be of value in terms of growing of certain food items (maize, soya etc.) and are rated as “arable” in terms of land capability.

Table 2 – Agricultural Potential

Agric_Pot	Agric_Pot1	Agric_Pot2	Total Area	% Area
1 = Moderate to Good	1	B0, A1	259.05	50.04
2 = Moderate to Poor	2	B1, D2	150.92	29.15
3 = Poor to Unsuitable	3	D2, C1x	36.13	6.98
4 = Poor	4	D2	14.67	2.83
5 = Unsuitable	5	C1x	56.88	10.99
Total			**517.65**	**100.00**

A significant proportion of the area of concern rates as moderate to good (50.04% or 259.05ha) in terms of agricultural potential, with an additional area that rates as good grazing potential land in terms of the land capability, and moderate to poor in terms of its agricultural (arable) potential (29.15% or 150.92ha). This additional area is considered less productive in terms of dryland cultivation for food crop items, but has a better than average rating for good quality livestock grazing potential under natural (no irrigation or fertilisation) conditions.

There is good evidence (present land use) to believe that an economically successful agricultural development is viable for a significant proportion (79.19%) of the study area, with better than average (national average for the crop climate) yields being returned from the moderate and good (50.04%) agricultural potential sites.

2.4 Alternative Assessment

Based on the field information gained from the reconnaissance studies and an understanding of the geomorphology of the sites, the land capability was rated. This information has been used as an aid in determining the site sensitivity (Refer to Figures 2.4a and 2.4 c – Sensitivity Maps and 2.4b and 2.4d – Land Capability) which in turn have been used to compare the three candidate sites. The ultimate decision on the most sustainable and environmentally correct site for the Ash Disposal Facility will require more than just an understanding of the soils and land capability.

Of consequence to any sustainability equation is the consideration of the soil resource, and the concept of "No Net Loss", and although it is understood that this concept is seldom attainable for a development such as an Ash Disposal Facility (permanent structure), the concept is a good one and should be considered as a best practice limit to be aimed for wherever possible.

In considering the outcomes that have been used in measuring the alternatives for these studies the following variables were considered important:

Soils	Sensitivity of Soil
	Erosion Potential of Soil
	Soil Depth (ERD)
	Soil Structure and Workability
Land Capability	Arable Potential
	Grazing Potential
	Wilderness Potential
	Wetland Potential
Land Use	Presence of dwellings or people on the land
	Presence of Infrastructure
	Presence of livestock or cultivation on land

The ability of the earth scientist to assist the development and planners in obtaining the best alternative for a development is often found in the understanding of the interrelationship between the various disciplines.

A straight association is not always a true reflection of the sensitivity of a resource to impact, and might require that a weighting is attached to the particular aspect being considered. However, this is best left to the EAP as he/she has the cross section of the specialist information at hand.

Table 2.3 is a straight comparison of the three sites using a scale of 1 to 9, where 1 = Highly Suitable and 9 = Not Suitable, while Figure 2.3 is a graphic representation of the site sensitivities based primarily on soil and land capability variables.

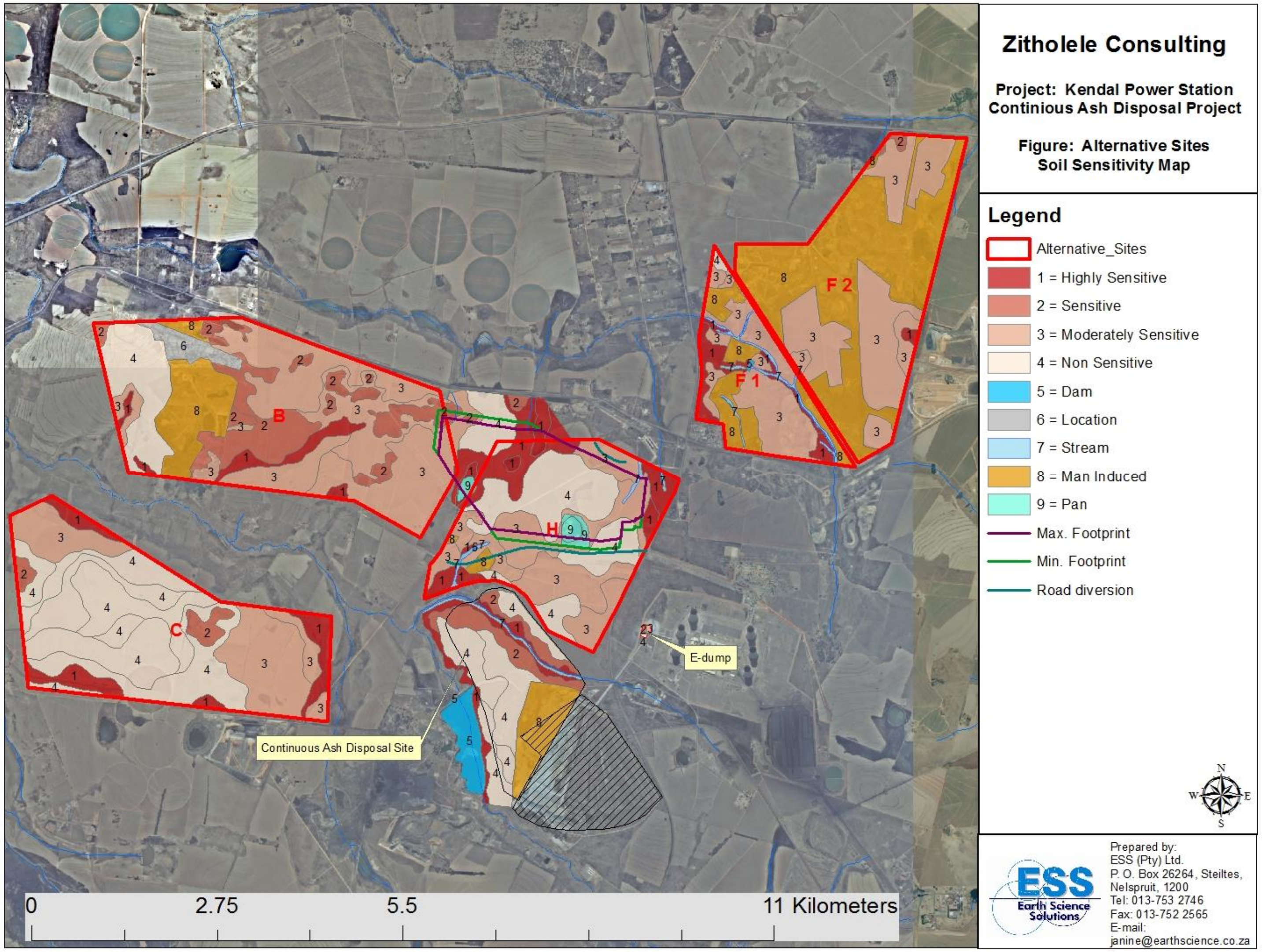

Figure 2.4a – Site Sensitivity Map – Proposed Ash Disposal Facility – Sites B, C F and H

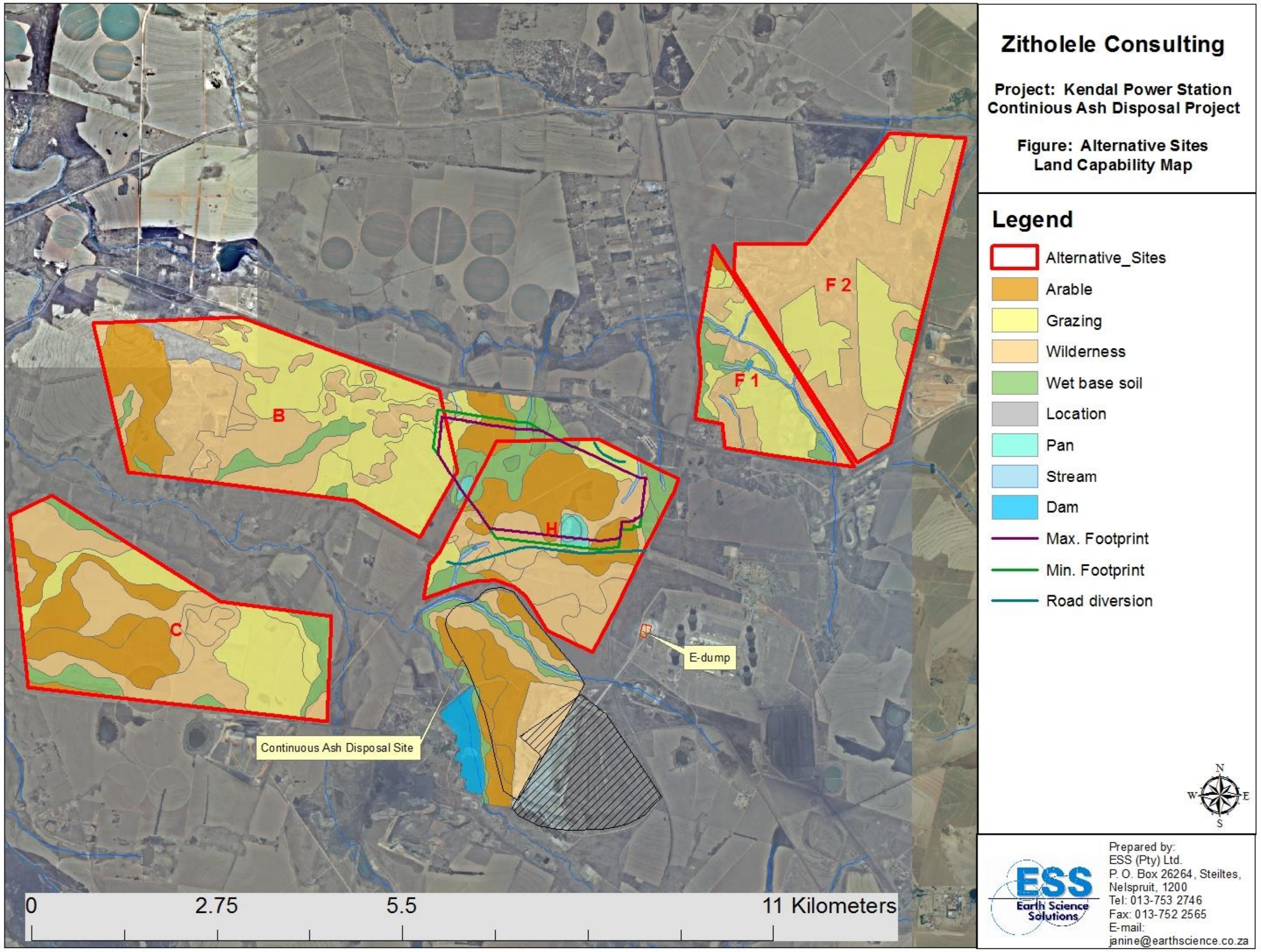

Figure 2.4b - Land Capability Map – Proposed Ash Disposal Facilities - Sites B, C F and H

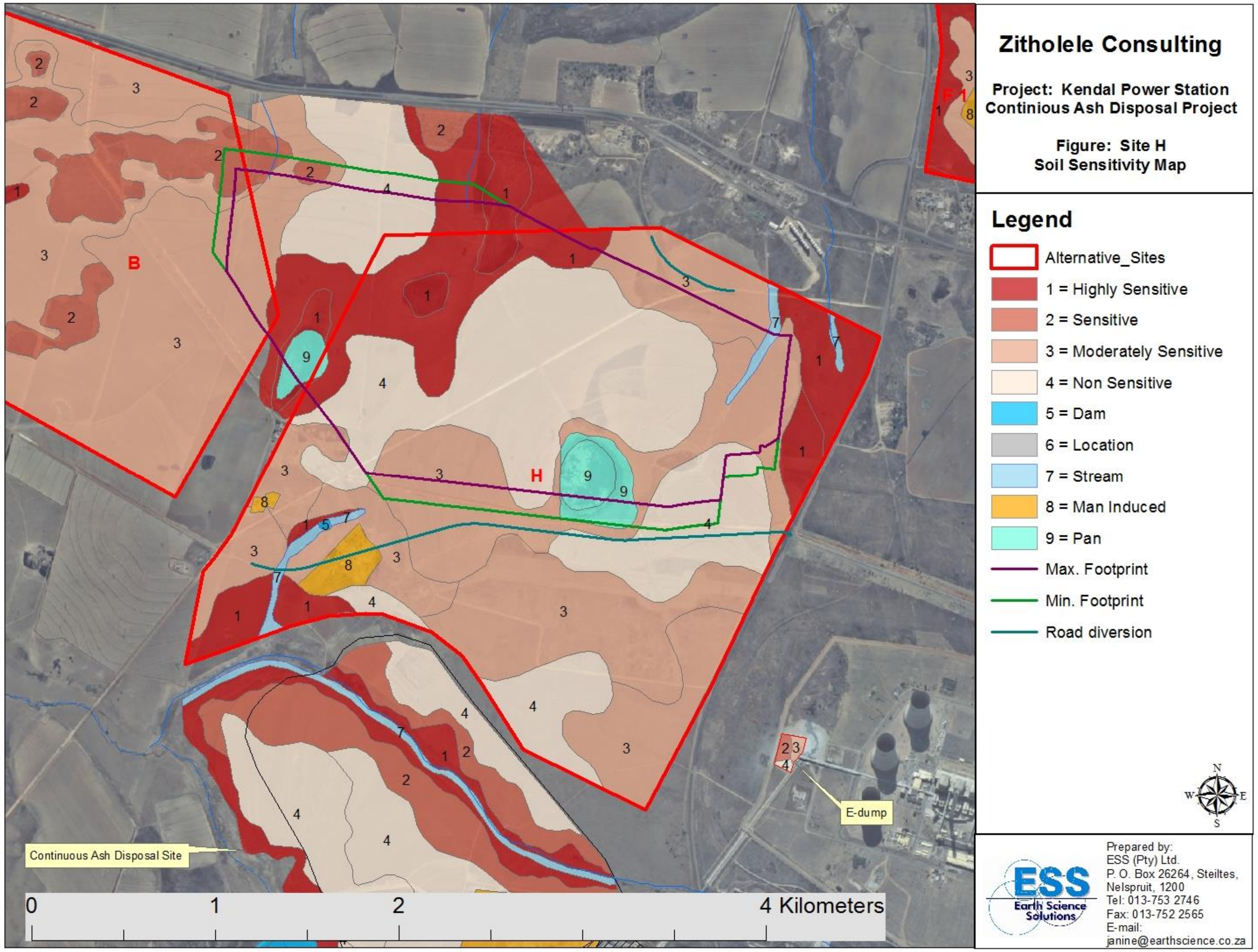

Figure 2.4c – Site Sensitivity Map – Proposed Ash Disposal Facility – Site H

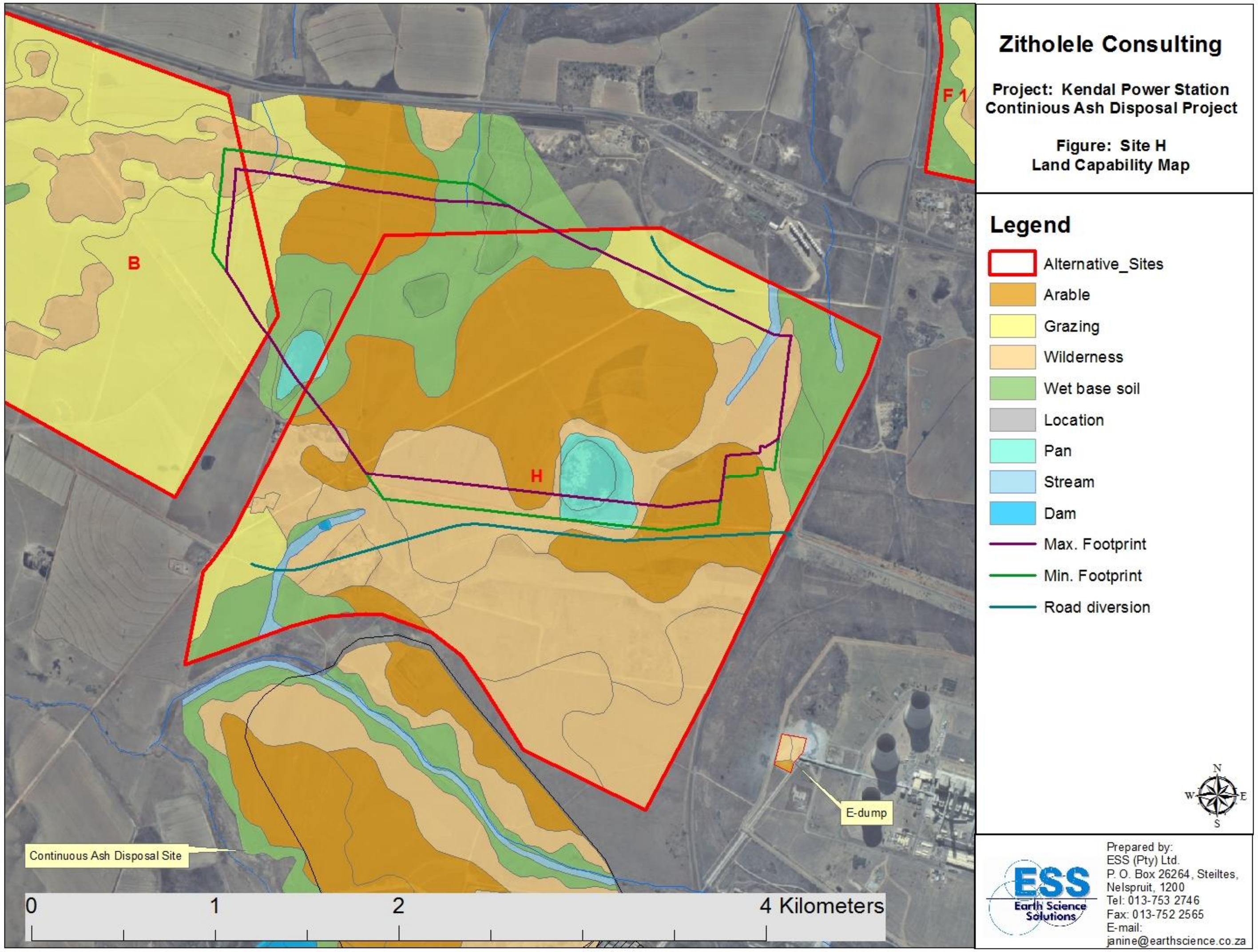

Figure 2.4d - Land Capability Map – Proposed Ash Disposal Facility – Site H

In summarising the outcomes of the alternatives for the specialist soils and land capability aspects the following pertain:

- Site B comprises better than average arable land and although mining of coal has occurred on the west central portion of the site, a significant portion is still available for agricultural use. No additional mining is apparent, and a significantly large informal settlement is present in the north western sector
- Site C has significantly large areas of wet based soils and wetland status land, and although mining is prevalent to the north of the proposed site, there is evidence that active mining is planned and has been initiated across much of the site in question.
- Site F has been impacted by mining, and very little land remains that could be used for commercial agriculture. Significant portions of the site have already been rehabilitated, and that which has not been rehabilitated is highly disturbed and will need to be actively reinstated if closure is to be obtained. There are very few settlers on the land, either formal or informal, and although the site does boarder on the Kendal Town lands to the south west there is sufficient buffer area that could be used to mitigate the impact on people. The disturbed nature of Site F and the fact that a significant proportion of the site has had the soils removed and stockpiled already is noteworthy. We are of the opinion that it is environmentally responsible to use disturbed sites for the deposition of permanent waste dumps than using soils and land that has the potential to sustain a food supply for the country.
- Site H has been impacted by commercial farming for the most part with significant areas of well-established maize and annual crops planted to both dryland cultivation as well as centre pivot irrigation.
- There is no mining on the area of concern and only very limited habitation other than the farm homestead and a small number of farm employee dwellings. The disturbed nature of Site H by agriculture is only significant in that the eco system services and socio economic aspects will be impacted.
- The Agricultural Potential Study returned ratings for a significant proportion of the study area of "moderate to good", a rating conducive to moderate arable potential under good management conditions and additions of pertinent fertilisers and water.
- In addition, additional areas (???ha) of the site are considered moderate grazing potential in terms of the land capability, and moderate to poor arable potential sites on the ASR system of agricultural potential

  We are of the opinion that it is environmentally responsible to use disturbed sites for the deposition of permanent waste dumps than using soils and land that has the potential to sustain a food supply for the country. Site H should therefore not be considered as the primary candidate site for an ashing facility in terms of the soil and land capability assessment

Based on these findings, it is evident that Site "F" is considered to be the best candidate site for an Ash Storage Facility.

It is however the opinion of the lead consultant and authorities based on the overall weighting of specialist inputs that Site "H" is the optimum site and should be considered in terms of impact assessment.

Table 2.4 – Alternative Assessment Matrix

KENDAL 30 YEAR ASH DUMP - SITE SENSITIVITY ANAYSIS

Ash Storage Facility - Alternatives Analysis Matrix

Considerations				Alternative							
				Site Option B		Site Option C		Site Option F		Site Option H	
Account	Sub-account	Indicator	Indicator weighting	Score	Description	Score	Description	Score	Description	Score	Description
Aspects of Physical Environment	Present Land Use	Habitation & Existing Use	0	3	Limited habitation associated with existing mining venture and on north western boundary. 15% under existing mining activity.	3	Limited to no habitation, but significantly more mining than is suggested by the aerial photographs used. Potentially 50% of area is either mined out is in process of being mined.	2	Existing and ongoing mining - rehabilitation and some informal settlements on edge of Kendal Townlands Approx 70% area disturbed by mining (still to be rehabilitated in places).	4	Area under commercial farming, with limited subsistance farming, farm dwellings and no existing mining.
		Cultivation or Grazing Usage	0	6	Significant area of cultivated annual pastures and commercial cropping - estimated that >70 of area is utilised, but soils are generally of a grazing land rating and status.	5	Area not mined out or disturbed by mining is under cultivation if not too wetHigh % of Cultivation - > 95% under irrigation and/or cultivated lands	2	Natural veld grass and limited cultivation on small areas within mining boundary. Highly disturbed and not very productive. Some rehabiltated ground could be reinstated for grazing once mining is completed.	6	Majority of the site is cultivated to commercial production of maize. Natural veld grasses confined to wet areas (Pans) and stream environments.
		Subsistance usage	0	4	Limited usage, but area of more formalised settlement (water and electricity installed) has grown since aerial imagery was produced.	1	None	2	None	2	None
	Sub-account value		0	13		9		6		12	
	Soils	Presence of sensitive soils	0	4	Some indications of wet based or transitional zone soils - Sensitive and require managemnt inputs. Wet based soils associated with waterways and possible lithological change in central portion of site (dolerite?).	5	Limited but significant area of wet based and/or Transitional Zone soils associated with the Pan structures in the northern sector (mined out in most cases) and undisturbed areas of wetland status soils along river system in the south and east.	2	Limited wet based and transitional zone soils associated with the minor water way - only moderately sensitive. Appear to have been left out of mining operation. Affected by dirty water and dust, and significant portion of site underlain by gravel layer (Soft and/or hard plinthite).	6	Significant areas of wet based and transitional zone soils associated with the Pan and stream/water ways - sensitive to highly sensitive with areas of wetlands and lateritic/hard plinthic barrier to water infiltration.
		Soil Workability	0	3	Sandy loams to silty clay loams for the most part - moderately easily worked for all but the wet based soils (significant area of proposed site)	5	Friable sandy loams to sandy clay loams - Easily worked and stored for all but the wetland status and wet based soils.	2	Modertely shallow sandy loams and silty clay loams where soils stilll exist- Generally easily worked and stored.	4	Modertely deep to deep sandy loams and silty clay loams with significant areas of utilisable soil cover. Moderately easy to easily worked, stored and rehabilitated.
		Erosion Sensitivity	0	4	Moderate to shallow and flat gradients, moderate to low clay, and poor organic matter content - Moderate to high erosion if not protected, or if impacted by vegetation removal.	4	Flat to undulating terrain - moderate clay probably, but low organic carbon content to soils - Moderate to high erosion index if not protected.	4	Flat to undulating terrain, moderate to shallow profiles with moderate to good grazing potential. Unprotected soil are sensitive to erosion. Rehabilitated areas need to be vegetated as soon as possible after re-instatement	4	Flat to undulating terrain, moderate to deep soil profiles with moderate to good grazing potential. Unprotected soil are sensitive to erosion. Rehabilitated areas need to be vegetated as soon as possible after re-instatement
	Sub-account value		0	11		14		8		14	
	Land Capability	Arable Potential of Soils	0	2	Generally moderately deep to shallow soil depth with transitional zone soils associated with a gravel or ferricrete layer at base - Limited arible potential unless activily farmed and additives included in overall costs.	6	Generally moderate to deeper soils - Moderate to good arible potential if cultivated and additives considered. Significant areas of wet based soils that cannot/should not be grazed or cultivated.	3	Very limited arable potential - generally shallow with limited wet based soils associated with the water way. 70% area disturbed by previous or existing mining, some rehabilitatied areas - grazing potential	4	Limited arable potential - generally moderately deep but profiles but with wet base to soil profiles. Generally good grazing potential land
		Grazing Potential of Soils	0	3	Significant but small areas of moist grassmands associated with wet based soils and transition zone - difficult to work and considered sensitive -At best moderate grazing potential on areas outside of the valley bottoms - west and estern areas.	5	Limited natural grassland savanha, and significant wet based or transitional zone soils, generally better than average to good grazing potential	3	Moderate grazing potential for majority of area (rehabilitated and small areas of remaining undisturbed lands).	6	Moderate to good grazing potential for majority of area, albeit that the majority of the site has been planted to commercial crops.
		Conservation Potential of Soils	0	3	Limited wet based and transiton zone soils - Need to be conserved	2	Limited shallow soils or soils with sensitive nature that need to be conserved	2	Limited wet based transitional zone soils associated with the teriary drainage channels and water way.	3	Occurrence of significant area of wet based transitional zone soils associated with the tertiary drainage channels and water way.
	Sub-account value		0	8		13		8		13	
	Overall Value		0.0	32	2	36	3	22	1	39	4

Notes:
The table is a straight comparison of the four sites using a scale of 1 to 9, where 1 = Highly Suitable and 9 = Not Suitable.
Lowest score = Best site for Ash Dump.

3. ENVIRONMENTAL IMPACT ASSESSMENT - PHILOSOPHY

With the baseline for the alternative study in hand, and with the consensus for Site "H" having been tabled as the overall best candidate site, the development plan for Site H was tabled.

The impact assessment has been based on the actions and activities as described in the development plan entitled "**KENDAL 30 YEAR ASH DISPOSAL FACILITY – CONCEPTUAL ENGINEERING DESIGN and dated 08th December 2014".**

The baseline information forms the basis for the existing state of the environment for the study area, the relative sensitivities and areas of concern having been highlighted and used as the basis for the Impact Assessment, with the establishment of Site "H" as the preferred option. (Refer to Figure 5.1a – Soil Sensitivity Map).

This report has been compiled in line with the South African Integrated Environmental Management Information Series (DEAT 2002), a guideline to the Impact Assessment philosophy and Significance Rating System.

This system aims to identify and quantify the physical environmental and/or social aspects of the proposed activities inclusive of any alternatives, to assess how these aspects will affect the existing state, and link the aspects to variables that have been defined in terms of the baseline study.

In addition, the impact assessment has defined a maximum acceptable level of impact for each of the activities or variables, inclusive of any standards, limits and/or thresholds, and has assessed the impact in terms of the significance rating as defined by the lead consultants.

The environmental aspects are not least of all part of the information that is needed in this decision making, with an understanding of how the soils and land capability will be affected being just part of the overall sustainability equation that needs to be balanced.

The principle of "No Net Loss" has been considered the baseline principle that should be aimed for wherever possible. However, the development/construction and operation of a mega ash disposal facility and its support infrastructure (pipelines, power reticulation, access roads and stormwater control facilities) and the fact that the structure is a permanent feature will challenge this concept.

Based on the outcomes of the impact assessment, the site specific management planning and mitigation measures have been defined and detailed. These include defining what the mitigation will do to reduce the intensity and probability of the impact, specify a performance expectation for the mitigation proposed, and ensure that the prescriptive mitigation proposed is clear, site specific and practical.

In addition, and as part of the practical management plan, a monitoring system has been defined and any legal limits or provisions listed.

As part of understanding the variables and the maximum acceptable levels of impact that will be considered by the authorities, a summary of the national legislation that pertains to soils has been considered. These will aid in setting the permissible standards and limits that can be considered, albeit that there are no prescribed limits available.

The following section outlines a summary of the South African Environmental Legislation that needs to be considered for any new development with reference to management of soil:

- *The law on Conservation of Agricultural Resources (Act 43 of 1983) states that the degradation of the agricultural potential of soil is illegal.*
- *The Bill of Rights states that environmental rights exist primarily to ensure good health and wellbeing, and secondarily to protect the environment through reasonable legislation, ensuring the prevention of the degradation of resources.*
- *The Environmental right is furthered in the National Environmental Management Act (No. 107 of 1998), which prescribes three principles, namely the precautionary principle, the "polluter pays" principle and the preventive principle.*
- *It is stated in the above-mentioned Act that the individual/group responsible for the degradation/pollution of natural resources is required to rehabilitate the polluted source.*
- *Soils and land capability are protected under the National Environmental Management Act 107 of 1998, the Environmental Conservation Act 73 of 1989, the Minerals Act 50 of 1991 and the Conservation of Agricultural Resources Act 43 of 1983.*
- *The National Veld and Forest Fire Bill of 10 July 1998 and the Fertilizer, Farm Feeds, Agricultural Remedies and Stock Remedies Act 36 of 1947 can also be applicable in some cases.*
- *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 minimized and remedied.*
- *The Minerals Act of 1991 requires an EMPR, in which the soils and land capability be described.*
- *The Conservation of Agriculture Resources Act 43 of 1983 requires the protection of land against soil erosion and the prevention of water logging and salinization of soils by means of suitable soil conservation works to be constructed and maintained. The utilization of marshes, water sponges and water courses are also addressed*.

In addition to the South African legal compliance as listed, this proposed development has also been assessed in terms of the International Performance Standards as detailed by the International Finance Corporation.

The IFC has developed a series of Performance Standards to assist developers and potential clients in assessing the environmental and social risks associated with a project and assisting the client in identifying and defining roles and responsibilities regarding the management of risk.

Performance Standard 1 establishes the importance of:

- Integrated assessment to identify the social and environmental impacts, risks, and opportunities of projects;
- Effective community engagement through disclosure of project-related information and consultation with local communities on matters that directly affect them; and
- The client's management of social and environmental performance throughout the life of the project.

Performance Standards 2 through 8 establish requirements to avoid, reduce, mitigate or compensate for impacts on people and the environment, and to improve conditions where appropriate.

While all relevant social and environmental risks and potential impacts should be considered as part of the assessment, Performance Standards 2 through 8 describe potential social and environmental impacts that require particular attention in emerging markets.

Where social or environmental impacts are anticipated, the client is required to manage them through its Social and Environmental Management System consistent with Performance Standard 1.

Of importance to this report are:

- The requirements to collect adequate baseline data;
- The requirements of an impact/risk assessment;
- The requirements of a management program;
- The requirements of a monitoring program; and most importantly;
- To apply relevant standards (either host country or other).

With regard to the application of relevant standards (either host country or other) there are no specific guidelines relating to soils and land use/capability, either locally or within the World Bank's or IFC's suite of Environmental Health and Safety Guidelines. The World Bank's Mining and Milling, Underground guideline does state, however, that project sponsors are required to prepare and implement an erosion and sediment control plan. The plan should include measures appropriate to the situation to intercept, divert, or otherwise reduce the stormwater runoff from exposed soil surfaces, tailings dams, and waste rock dumps.

Project sponsors are encouraged to integrate vegetative and non-vegetative soil stabilization measures in the erosion control plan.

Sediment control structures (e.g., detention/retention basins) should be installed to treat surface runoff prior to discharge to surface water bodies. All erosion control and sediment containment facilities must receive proper maintenance during their design life. This will be included in the appropriate management plans when they are developed at a later stage in the project's life cycle.

The variation in soil structure, texture and clay content of the soils combined with the presence of a prominent ferricrete (evaporite) layer at the base of many of the soil profiles ("C" Horizon), all make for a complex of natural conditions that are going to be extremely difficult to replicate during the rehabilitation stage and at closure.

The potential and probable loss of soil water and the "perched" aquifer that is believed to occur as a result of the ferricrete inhibiting/barrier layer will need to be assessed and understood as a function of the ecological balance.

The low levels of organic carbon and relatively low nutrient stores noted for many of the soils will also require that a sound management plan is adopted based on the best impact assessment information.

The concept of "**utilisable soil**" storage will be tabled as a basic management tool, and a function of good environment practise.

Soils are considered sensitive and important to the ecological cycle while forming an integral part of the eco system services.

Erosion and compaction are two of the more sensitive aspects that need to be considered and which will occur to varying degrees and, although tempered by the relative flatness of the terrain, they will need a well formulated management plan and adequate engineering if they are exposed and disturbed.

In addition, the variable depth profiles of the materials mapped are of concern as the depths of utilisable soil that can be stripped and stored will make for challenging management if all of the utilisable soils are to be harvested (large volumes).

Soils are extremely important to the long term sustainability of any project and will need to be stripped during construction, stored and maintained during the operational stage, and reinstated at closure (rehabilitation and emplacement of stored soils).

The impact of development on the soils and the resultant change in the land capability will be varied due to the differences associated with the soil forming processes and the resultant variation in the soil physical and chemical composition. The materials range from well-developed in-situ derived sandy and silty loams associated with the sedimentary lithologies to clay rich and well-structured sandy clays and clay loams associated with the more basic intrusive lithological units. These are contrasted with more recent colluvial and alluvial derived materials that show less well defined pedogenisis and comprise a range of structure and texture.

These factors will be important in the environmental assessment and final management plan that is tabled, with the “separation” and management of the differing materials at the removal stage (construction) forming the basis for economically and sustainable rehabilitation at closure.

The moderately complex nature of the geology (physical and chemical) and geomorphology of the area and the semi-arid climate, all play a significant role in the soil forming process, and have a bearing on the sensitivity and/or vulnerability of the materials when being worked or disturbed.

These factors are important not only in planning the construction and operational activities, but will determine the success of the rehabilitation planning for the future.

4. ENVIRONMENTAL IMPACT ASSESSMENT METHODOLOGY

4.1 Impact Assessment Methodology

The impacts will be ranked according to the methodology described below. Where possible, mitigation measures will be provided to manage impacts. In order to ensure uniformity, a standard impact assessment methodology will be utilised so that a wide range of impacts can be compared with each other. The impact assessment methodology makes provision for the assessment of impacts against the following criteria:

- Significance;
- Spatial scale;
- Temporal scale;
- Probability; and
- Degree of certainty.

A combined quantitative and qualitative methodology was used to describe impacts for each of the aforementioned assessment criteria. A summary of each of the qualitative descriptors along with the equivalent quantitative rating scale for each of the aforementioned criteria is given in **Table 4-1**.

Table 4-1: Quantitative rating and equivalent descriptors for the impact assessment criteria

Rating	Significance	Extent Scale	Temporal Scale
1	VERY LOW	*Proposed site*	Incidental
2	LOW	*Study area*	Short-term
3	MODERATE	*Local*	Medium-term
4	HIGH	*Regional / Provincial*	Long-term
5	VERY HIGH	*Global / National*	Permanent

A more detailed description of each of the assessment criteria is given in the following sections.

Significance Assessment

Significance rating (importance) of the associated impacts embraces the notion of extent and magnitude, but does not always clearly define these since their importance in the rating scale is very relative. For example, the magnitude (i.e. the size) of area affected by atmospheric pollution may be extremely large (1 000 km^2) but the significance of this effect is dependent on the concentration or level of pollution. If the concentration is great, the significance of the impact would be HIGH or VERY HIGH, but if it is diluted it would be VERY LOW or LOW. Similarly, if 30 ha of a grassland type are destroyed the impact would be VERY HIGH if only 100 ha of that grassland type were known. The impact would be VERY LOW if the grassland type was common. A more detailed description of the impact significance rating scale is given in Table 4.2 below.

Table 4-2: Description of the significance rating scale

Rating		Description
5	Very high	Of the highest order possible within the bounds of impacts which could occur. In the case of adverse impacts: there is no possible mitigation and/or remedial activity which could offset the impact. In the case of beneficial impacts, there is no real alternative to achieving this benefit.
4	High	Impact is of substantial order within the bounds of impacts, which could occur. In the case of adverse impacts: mitigation and/or remedial activity is feasible but difficult, expensive, time-consuming or some combination of these. In the case of beneficial impacts, other means of achieving this benefit are feasible but they are more difficult, expensive, time-consuming or some combination of these.
3	Moderate	Impact is real but not substantial in relation to other impacts, which might take effect within the bounds of those which could occur. In the case of adverse impacts: mitigation and/or remedial activity are both feasible and fairly easily possible. In the case of beneficial impacts: other means of achieving this benefit are about equal in time, cost, effort, etc.
2	Low	Impact is of a low order and therefore likely to have little real effect. In the case of adverse impacts: mitigation and/or remedial activity is either easily achieved or little will be required, or both. In the case of beneficial impacts, alternative means for achieving this benefit are likely to be easier, cheaper, more effective, less time consuming, or some combination of these.
1	Very low	Impact is negligible within the bounds of impacts which could occur. In the case of adverse impacts, almost no mitigation and/or remedial activity are needed, and any minor steps which might be needed are easy, cheap, and simple. In the case of beneficial impacts, alternative means are almost all likely to be better, in one or a number of ways, than this means of achieving the benefit. Three additional categories must also be used where relevant. They are in addition to the category represented on the scale, and if used, will replace the scale.
0	No impact	There is no impact at all - not even a very low impact on a party or system.

Spatial Scale

The spatial scale refers to the extent of the impact i.e. will the impact be felt at the local, regional, or global scale. The spatial assessment scale is described in more detail in **Table 4-3.**

Table 4-3: Description of the significance rating scale

Rating		Description
5	Global/National	The maximum extent of any impact.
4	Regional/Provincial	The spatial scale is moderate within the bounds of impacts possible, and will be felt at a regional scale (District Municipality to Provincial Level).
3	Local	The impact will affect an area up to 10 km from the proposed site.
2	Study Site	The impact will affect an area not exceeding the Eskom property.
1	Proposed site	The impact will affect an area no bigger than the ash disposal site.

Duration Scale

In order to accurately describe the impact, it is necessary to understand the duration and persistence of an impact in the environment. The temporal scale is rated according to criteria set out in **Table 4-4**.

Table 4-4: Description of the temporal rating scale

Rating		Description
1	Incidental	The impact will be limited to isolated incidences that are expected to occur very sporadically.
2	Short-term	The environmental impact identified will operate for the duration of the construction phase or a period of less than 5 years, whichever is the greater.
3	Medium term	The environmental impact identified will operate for the duration of life of facility.
4	Long term	The environmental impact identified will operate beyond the life of operation.
5	Permanent	The environmental impact will be permanent.

Degree of Probability

Probability or likelihood of an impact occurring will be described as shown in **Table 4-5** below.

Table 4-5: Description of the degree of probability of an impact occurring

Rating	Description
1	Practically impossible
2	Unlikely
3	Could happen
4	Very Likely
5	It's going to happen / has occurred

Degree of Certainty

As with all studies it is not possible to be 100% certain of all facts, and for this reason a standard "degree of certainty" scale is used as discussed in Table 4.6. The level of detail for specialist studies is determined according to the degree of certainty required for decision-making. The impacts are discussed in terms of affected parties or environmental components.

Table 4-6: Description of the degree of certainty rating scale

Rating	Description
Definite	More than 90% sure of a particular fact.
Probable	Between 70 and 90% sure of a particular fact, or of the likelihood of that impact occurring.
Possible	Between 40 and 70% sure of a particular fact or of the likelihood of an impact occurring.
Unsure	Less than 40% sure of a particular fact or the likelihood of an impact occurring.
Can't know	The consultant believes an assessment is not possible even with additional research.
Don't know	The consultant cannot, or is unwilling, to make an assessment given available information.

Quantitative Description of Impacts

To allow for impacts to be described in a quantitative manner in addition to the qualitative description given above, a rating scale of between 1 and 5 was used for each of the assessment criteria. Thus the total value of the impact is described as the function of significance, spatial and temporal scale as described below:

$$Impact\ Risk = \frac{(Significance + Spatial + Temporal)}{3} \times \frac{Probability}{5}$$

An example of how this rating scale is applied is shown below:

Table 4-7: Example of Rating Scale

Impact	Significance	Spatial Scale	Temporal Scale	Probability	Rating
	LOW	*Local*	Medium-term	*Could Happen*	
Impact to air	**2**	***3***	**3**	**3**	**1.6**

Note: The significance, spatial and temporal scales are added to give a total of 8, that is divided by 3 to give a criteria rating of 2.67. The probability (3) is divided by 5 to give a probability rating of 0.6. The criteria rating of 2.67 is then multiplied by the probability rating (0.6) to give the final rating of 1,6.

The impact risk is classified according to five classes as described in the **Table 4-8** below.

Table 4-8: Impact Risk Classes

Rating	Impact Class	Description
0.1 – 1.0	**1**	**Very Low**
1.1 – 2.0	**2**	**Low**
2.1 – 3.0	**3**	**Moderate**
3.1 – 4.0	**4**	**High**
4.1 – 5.0	**5**	**Very High**

Therefore, with reference to the example used for air quality above, an impact rating of 1.6 will fall in the Impact Class 2, which will be considered to be a low impact.

Cumulative Impacts

It is a requirement that the impact assessments take cognisance of cumulative impacts. In fulfilment of this requirement the impact assessment will take cognisance of any existing impact sustained by the operations, any mitigation measures already in place, any additional impact to environment through continued and proposed future activities, and the residual impact after mitigation measures.

It is important to note that cumulative impacts at the national or provincial level will not be considered in this assessment, as the total quantification of external companies on resources is not possible at the project level due to the lack of information and research documenting the effects of existing activities. Such cumulative impacts that may occur across industry boundaries can also only be effectively addressed at Provincial and National Government levels.

Notation of Impacts

In order to make the report easier to read the following notation format is used to highlight the various components of the assessment:

- Significance or magnitude- IN CAPITALS
- Temporal Scale – in underline
- Probability – in *italics and underlined*
- Degree of certainty - in **bold**
- Spatial Extent Scale – in *italics*

Of consequence to the soils and land capability of the areas to be affected are the changes that the activities and related support aspects being planned will have on the existing physical and socio economic state of the environment.

5. ENVIRONMENTAL IMPACT ASSESSMENT/STATEMENT

The EIA methodology and philosophy is covered in the preceding sections, and with the alternatives assessment concluded a significant amount of baseline information is available along with an understanding of the activities and how they will impact the soils and land capability during the construction and operation of the proposed ash conveyencing and disposal.

The engineering design and project description have been used as the basis for the EIA and associated EMP (Refer to Figure 5.1a – Engineering Design – Site "H"), while the outcomes of the baseline studies (soils, land capability and Agricultural Potential Study) and sensitivity analysis is detailed in Figure 5.1b attached

Based on these factors and outcomes, an assessment (EIA) of the environmental impacts that these activities might produce has been carried out and measured against the existing environmental state for Site H using the significance rating supplied.

This section assesses and measures/quantifies where possible the environmental aspects of the **activities** in terms of how they will affect the **existing state/status quo**, and details where possible/available the maximum acceptable level of impact for each of the variables listed.

Based on these findings, the **significance/impact risk** is rated in terms of its unmanaged and managed state, with the management recommendations forming the basis of the Environmental Management Plan (Chapter 6).

Of significance to the proposed development and the sustainability of any project are the sensitivities of many of the soils (Refer to Figure 5.1b).

The sensitivities considered important when assessing the soil environment include, soil depth, soil structure and texture (clay content etc.), the chemical composition (organic carbon etc.) and the soils erodibility and compactability. These variables are often manifest by particular soil features or resultant land forms and variations in the overall geomorphology, and are in almost all cases associated with other ecological aspects or considerations of biodiversity importance. The eco system services have also been considered as part of the Agricultural Potential Study.

At the extreme of sensitivity or vulnerability are the wetlands and wet based soils. In terms of the wetland delineation guidelines and the legal status of wetlands the highly sensitive areas need to be considered carefully if they are within the area of proposed impact.

There are no off-site activities included in this Environmental Impact Assessment, while the alternatives were considered. The assessment is confined to the project footprint (Site "H") and its immediate surroundings, and as such the "spatial extent is regarded as "Site Only" or at worst "Localised" depending on how far the effects of erosion are predicted to extend.

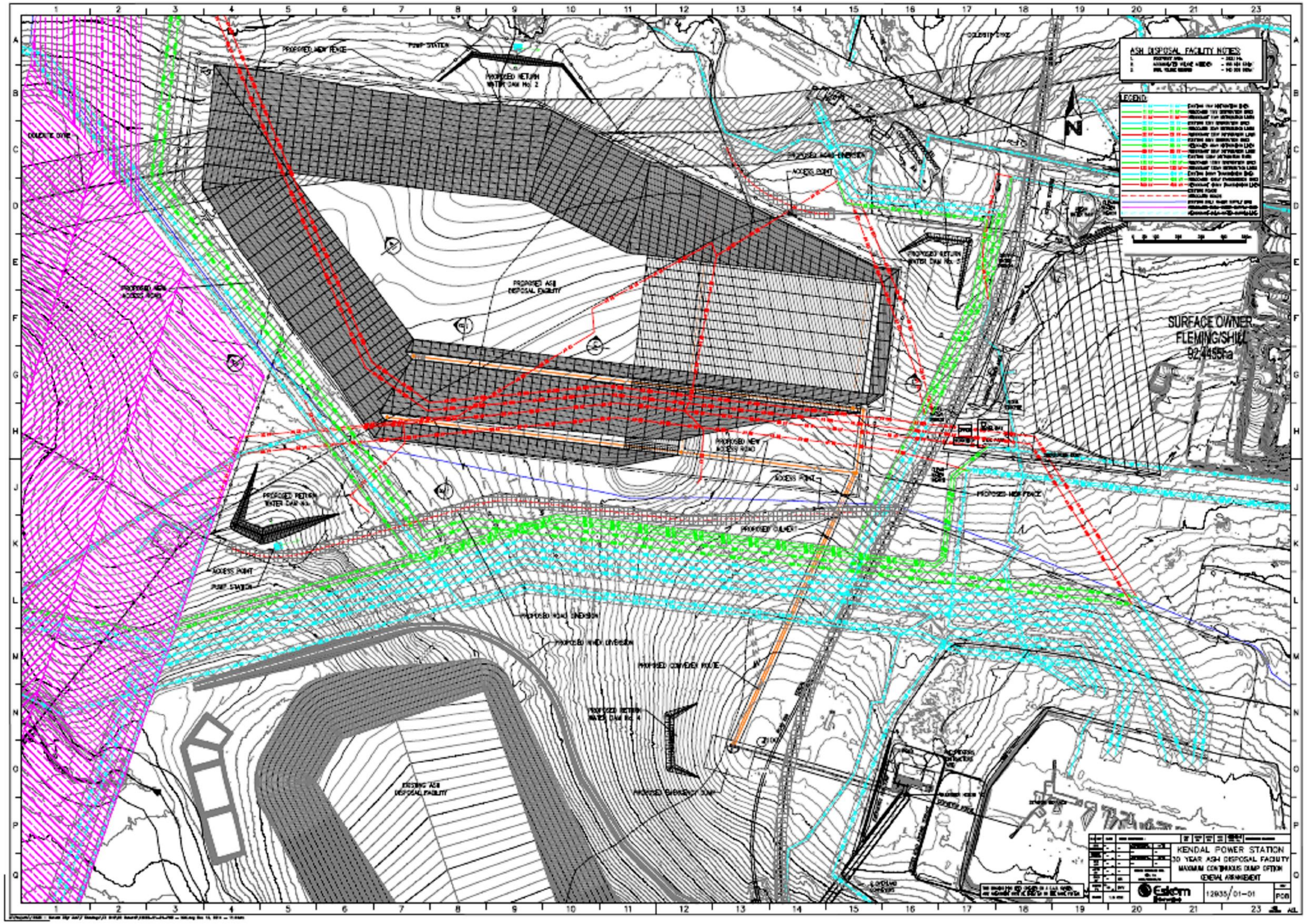

Figure 5.1a – Engineering Design – Site “H”

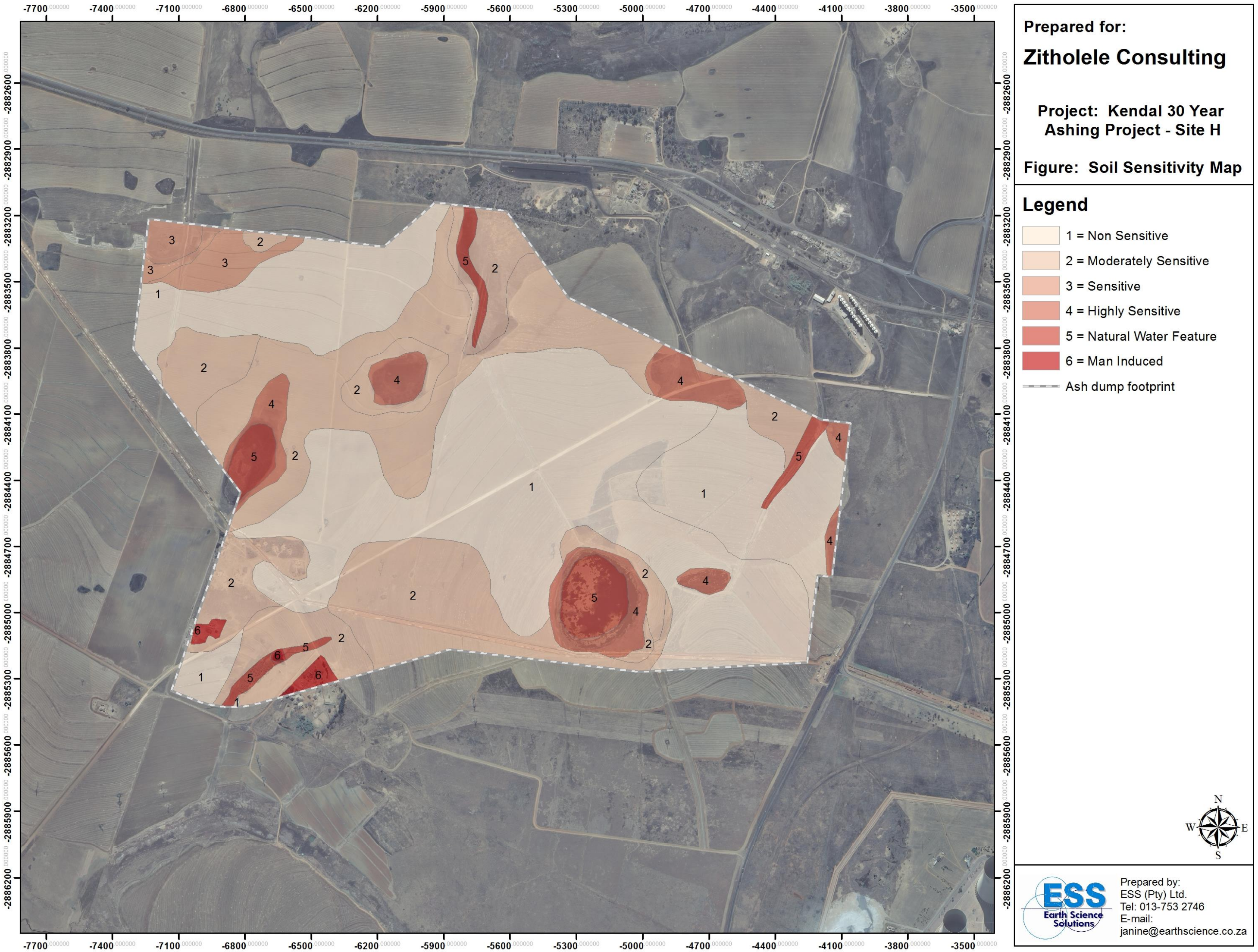

Figure 5.2 – Soil Sensitivity Map – Site H

The infrastructure planned for the facility will include (Refer to Design Reports) some large and heavy structures and relatively deep excavations (return water dams, ash facility liner and pump installations). These will entail the removal of significant quantities of soil, and possibly the complete removal of soil and soft overburden in places were the foundations for the larger structures (dams) are to be excavated.

The conveyer route and maintenance/access roadways will required less engineering as the size and weight of implements and machinery will be relatively much smaller/less, albeit that they will still require strong foundations with well-engineered sub-base for all plinth footings (conveyer and all above ground piping and stream crossings). These soils will however all be sterilized and lost from the system for the life of the operation and possibly beyond in the case of the permanent facility (Ash Disposal Facility).

A number of site specific baseline (existing environment) conditions are of special significance and need mention here if the relative impacts of the activities being planned are to be understood.

Of significance are:

- The underlying ferricrete layer (inhibiting layer), and its function as a barrier to soil water loss down the profile. This will in almost all cases [deep foundations or facilities (dams etc.)] be destroyed and possibly removed from the system where it exists;
- All/any pan structures that classify as wetlands are considered to be ecologically highly sensitive and important;
- The significant area of wet based soil that is being considered as part of the footprint to the developments including the PCDs.;
- The relatively low clay content of all but the more basic derived soils and the low organic carbon render most of the soils susceptible to erosion, while,
- The wet based soils and some of the more basic derived soils will compact if subjected to heavy loads.

These conditions will have a bearing on the ratings being assigned to the overall impact statement as loss of these features will have a definite localised negative impact that is of significance to the ecological functionality of the area. These variables have a bearing on the management recommendations made.

In addition to the baseline soil and land capability for the proposed site is the pre-development conditions or status quo for the area of concern. For the most part the site comprises commercial farmlands that are being cultivated to annual crops (cereals, potatoes and soya beans) or pastures for commercial livestock farming.

The status quo constitutes a brownfields environment, with significant negative impacts associated with the farming ventures. These have been assessed in some detail, albeit that little information is available of the original unaffected environment. The impacts will be associated with:

- The changes to the soil physical and chemical composition, the potential contamination (over supply and thus contamination by fertilisers that cannot be taken up by the plants and which will leach into the soil water and ultimately the groundwater environment),
- Erosion and loss of soils from unprotected cultivation and the effects of wind and water and the impacts of the added sedimentary load on the streams and rivers/dams of the area,
- Compaction by farm vehicles on unprotected lands and
- The contamination of the soils from hydrocarbon spills from farm implements.

These impacts have been taken into account when assessment of the proposed development is considered in its unmanaged and unmitigated state.

5.1 Planned Ash Disposal Facility Activities

The key activities planned for the development include:

- A fixed conveyor will be constructed from the existing Emergency Disposal Facility (E-Disposal) at the power station and will cross under Road 545 to the other side of the road were a proposed new Emergency Disposal Facility (E-Disposal Facility) will be constructed;
- Fixed conveyors will extend from the proposed new E-Disposal Facility towards the new proposed ADF on to which extendable and then shift-able conveyors will be fixed in order to dispose ash on the footprint of the proposed new ADF;
- Ashing on the proposed new ADF footprint will commence from the eastern side of the footprint towards the western end of the footprint;
- A 1:15 sloped ramp will be constructed on the eastern side of the proposed new ADF and will reach the maximum height of the proposed new ADF, 75 metres;
- Several power lines will be diverted:

    - ✓ 400 kV: 2 No. off
    - ✓ 88 kV: 2 No. off
    - ✓ 22 kV: 2 No. off
    - ✓ 132 kV: 2 No. off

- The proposed new ADF is tapered on the south western corner due to parcels of land that have mining rights attached to them, situated on the western side of the site, and the need to avoid utilising these parcels of land;
- The proposed new ADF will have a ring access road constructed around its perimeter together with stormwater canals intercepting impacted runoff and directing to a pollution control dam;
- The Kusile Bulk Water line **will not** be relocated (for Scenario 1 only);
- Four (4) proposed new dams are to be constructed. Two (2) pollution control dams (PCD) at the proposed new ADF, one (1) PCD at the proposed new E-Disposal Facility and one (1) clean water dam. Pump stations will be constructed at each of the dams;
- Road D1390 which runs through the proposed new ADF footprint will need to be diverted. The new diverted alignment of the road is on the southern side of the proposed new ADF and intersects with the access road leading to the Kendal Power Station main entrance.;
- The new diverted Road D1390 will have a 40 metre road reserve;
- There will be three (3) access points to the proposed new ADF;
- For both the Maximum and Minimum Continuous Disposal Facility Options, a distance of 500 metres has been achieved between the existing silos, on the north eastern side of the proposed new ADF, and the perimeter of the proposed ADF;
- The liner construction will be staged in Three (3) year stages. At any given point there will be 1 – 2 years of available footprint of constructed liner;
- The starter ramp wall for the proposed new ADF will be constructed with bulldozers. The rest of the proposed new ADF will be constructed with the conveyor-stacker system;

With an understanding of the activities that will occur as part of the proposed project, the construction and operational activities and support facilities and its associated infrastructure (conveyencing of the waste materials to the ash disposal site, and the management and reticulation of the dirty water), it is concluded that the **major** concerns and probable impacts that could affect the soils and associated land capability are associated with:

- The loss of the soil resource due the **change in land use** and the removal of the resource from the existing system (Sterilisation). These conditions are generally associated with the construction of the facility and its support infrastructure. The proposed waste depositional activities will potentially result in the complete loss of the soil resource for the life of the project. In the case of the ADF footprint this will be permanent, while some, or all of the support activities will be removed and the footprint rehabilitated. The ADF is planned to be capped and top dressed with soil.
- The on-going management of waste as the impact could potentially sterilise the soils permanently, if not removed/striped, stored and well managed;
- The loss of the soil resource due to **erosion** (wind and water) of unprotected materials due to the removal of vegetative cover and/or topsoil;
- The loss of the utilisation potential of the soil and land capability due to **compaction** of areas adjacent to the constructed facilities by vehicle and construction activities;
- Loss of the resource due to **removal** of materials for use in other activities (dam wall construction, development of berms and the storage of the soils in stockpiles);
- The **contamination** of the resource due to spillage of waste materials and the possibility of spillage of reagents that are transported to the site or used for the maintenance and operation of the infrastructure (conveyers etc.);
- The **contamination** of stored or in-situ materials due to dust or dirty water from the project area and transport routes;
- The loss of the soil utilisation potential due to the **disturbance** of the soils and potential loss of nutrient stores through leaching and de-nitrification of the stored or disturbed materials.

5.2 Impact Assessment

5.2.1 Construction Phase

Issue - ***Loss of utilisable resource (sterilization and erosion), compaction and contamination or salinization.***

The construction phase will require:

- The stripping of all utilisable soil (Top 250mm to 700mm depending on activity);
- The preparation (levelling and compaction) of lay-down areas, foundations and pad footprint areas for stockpiling of utilisable soil removed from the footprint to the ADF, Pollution Control Dams (PCD) and Soil Stockpiles (SS),
- The stormwater management system (Dams, Water Reservoir etc.), and the foundations for the Site Offices and Site Workshops and all related support infrastructure;
- The clearing, stripping and stockpiling from the construction of all access and Conveyencing and Haulage Ways, Electrical Servitudes and Water Reticulation (pipelines and overhead power lines);
- The use of heavy machinery over unprotected soils;
- The creation of dust and loss of materials to wind and water erosion, and

- The possible contamination of the soils by dirty water, chemicals and hydrocarbons spills (dust and dirty water runoff);

Impact Risk

The loss of the utilisation of the soil resource will negatively impact the land use practice of low to moderate intensity livestock grazing and commercial cultivation of cereal crops (major land use activities) being undertaken on the dryland soils at present. These activities are perceived to be of great economic benefit to the local economy and land owners and contribute to the ecosystem services.

The construction for the Ash Disposal Facility and its support activities will, if un-managed and without mitigation have a **definite,** MODERATE to HIGH negative significance, that will affect the *development site and its immediate* surroundings for the medium to long term (life of the project and possibly beyond), and it is *going to occur*.

The proposed activities will, during construction result in:

- The loss of the soil materials, and as a result the use of the resource with the associated negative effects on the eco system services;
- Have the potential for contamination (hydrocarbon and reagent chemical spills, raw materials and spillage of coal, etc.), compaction of working/laydown areas and storage facility footprint and the potential for erosion (wind and water – dust and suspended solids) over unprotected/disturbed areas;
- Have a moderate to high negative intensity potential ranking based on the confined (limited to footprint of impact) nature/design of the facility and associated infrastructure;
- An impact that will continue throughout the construction phase and into the operational phase;
- Will be permanent but reversible (can be broken down and rehabilitated) for all but the actual depositional facility, and
- Is confined to the site only - localised.

However, with management, the loss, degree of contamination, compaction and erosion of the resource can be mitigated and reduced to a level that is more acceptable.

The reduction in the risk rating of the impact can be achieved by:

- Limiting the area of impact to as small a footprint as possible, inclusive of the resource (soils) stockpiles and the length of servitudes, access and haulage ways and conveyencing systems wherever possible;
- Construction of the facility and associated infrastructure over the less sensitive soil groups (reduce impact over wetlands and soils sensitive to erosion and/or compaction);
- An awareness of the length of time that the resource (soil) will need to be stored and managed;
- The development and inclusion of soil management as part of the general housekeeping operations, and the independent auditing of the management;
- Concurrent rehabilitation of all affected sites that are not required for the operation;
- The rehabilitation of temporary structures and footprint areas used during the feasibility investigation (geotechnical pits, trenching etc.) and the construction phase;

- Effective soil stripping during the less windy months when the soils are less susceptible to erosion;
- Separation of the utilisable soils and wet base materials (inclusive of any ferricrete) from each other and from the soft overburden;
- Effective cladding of the berms and soil stockpiles/heaps with vegetation or large rock fragments, and the minimising of the height of storage facilities to 15m and soil berms to 1,5m wherever possible;
- Restriction of vehicle movement over unprotected or sensitive areas, this will reduce compaction;
- Soil amelioration (cultivation) to enhance the oxygenation and growing capability (germination) of natural regeneration and/or seed within the stockpiled soils (maintain the soils viability during storage) and areas of concurrent rehabilitation.

It is noted within the industry, that failure to manage the impacts on this important resource (soil) will result in the total loss of the resource, with a resultant much higher significance rating.

Residual Impact

The above management procedures will **probably** reduce the negative significance rating and resultant risk impact to a MODERATE LOW rating that will be confined to the *development site and its immediate (500m) surroundings* in the medium term. Based on the historical actions of the proponent these actions are *very likely to occur.*

Table 5.2.1 - Construction Phase Risk Impact

PRE-CONSTRUCTION & CONSTRUCTION PHASE									
Activity	Description of Impact	Impact type	Spatial Scale	Duration	Significance	Probability	Rating	Mitigation Measures	Interpretation
Exploration and Geotechnical,	Loss of soil resource	Existing	1	2	2	5	1.7 - LOW	Removal of all structures, backfilling of sumps and revegetation of footprint of disturbance and tracks if needed	The land use in the area (agriculture) has both erosion and compaction associated with it, resulting in dust and sedimentation on streams and rivers.
		Cumulative	1	2	1	5	1.3 - LOW		The land clearing for exploration drilling and pitting will have only minor imacts and will not contribute significantly to the risk rating
		Residual	1	1	1	4	0.8 - VERY LOW		The impact can be mitiagted to a very low risk rating by applying mitigation measures
Environmental Studies and Design	Loss of soil resource	Existing	1	2	2	5	1.7 - LOW	Backfilling of any soil pits and rehabilitation of any tracks . Revegetation of soil pit footprint if necessary.	The land use in the area (agriculture) has both erosion and compaction associated with it, resulting in dust and sedimentation on streams and rivers.
		Cumulative	1	2	1	5	1.3 - LOW		The land clearing for exploration drilling and pitting will have only minor imacts and will not contribute significantly to the risk rating
		Residual	1	1	1	4	0.8 - VERY LOW		The impact can be mitiagted to a very low risk rating by applying mitigation measures
Clearing of footprint for access onto site, construction of laydown areas for soil stockpile and soft overburden from footprint to dam excavations (RWD) and ADF. Clearing for the erection of security fencing and clearing and construction of support infrastructure (administrative buildings, satallite workshop etc.) to the ADF.	Loss of soil utilisation potential for the project footprint	Existing	3	3	4	5	3.3 - HIGH	Remoeval of all utilisable soil and storage of the same. Protect from impacts of erosion, compaction and contamination. Vegetate and/or cover with rock rap.	The commercial use of the land in the study area for food production will be perminantly lost from the ADF footprint
		Cumulative	3	3	4	5	3.3 - HIGH		Land clearing will imact significantly on soil erosion and compaction with a high risk of salinisation, sterilisation and contamination while being worked on.
		Residual	2	3	3	4	2.1 - MOD		Well managed stockpiles of soil and soft overburden resource will assist rehabilitation and final covering of ADF.
	Loss of vegetative cover and topsoil protection - possible erosion, the perminant loss of resource downslope and the impact of sedimentary load on receiving systems (streams, rivers pan etc.)	Existing	2	3	3	4	2.1 - MOD	Minimisation of footprint of impact, use of high floatation tires on all construction vehicles, removal and storage of utilisable soil and the re-vegetation and/or rock cover to all stored materials. Concurent rehabilitation where possible. Use of vetiver grass as erosion prevention ahead of clearing where erosion is a considered risk	The commercial use of the land in the study area for food production will be perminantly lost from the ADF footprint
		Cumulative	2	3	3	4	2.1 - MOD		Land clearing will imact significantly on soil erosion and compaction with a high risk of salinisation, sterilisation and contamination while being worked on.
		Residual	2	3	2	4	1.9 - LOW		Well managed stockpiles of soil and soft overburden resource will assist rehabilitation and final covering of ADF.
	Loss of soil resource and utilisation potential due to contamination by reagents and hydrocarbons spills and/or dirty water	Existing	2	3	3	4	2.1 - MOD	Restriction/minimisation of movement and servicing of vehicles, spillage from haulage systems and vehicles and the bunding of all services areas.	Impact from farming activities and use of heavy mechinary over unprotected soils will be negative and moderate.
		Cumulative	2	3	3	4	2.1 - MOD		Mining and the utilisation of heavy mechanery on unprotected soils will result in loss of resource and potential increase in sedimentation to receiving bodies, while the use of dirty water for dust suppression and the spillage of raw materials (ash) and hydrocarbons from vehicles will negativily influence the soils and associated land capability.
		Residual	2	3	2	4	1.9 - LOW		Well managed vehicle fleets and the control of and management of dirty water movement and raw material/waste spillage will reduce the overall impact
	Loss of resource and its utilisation potential due to compaction over unprotected ground/soil.	Existing	2	3	3	4	2.1 - MOD	Minimise the footprint of impact, restrict vehicle movement to areas of need, remove utisable soil to recommended depth, stockpile and then construct facilities. Rehabilitate areas once usefulness is completed.	Impact from farming activities and use of heavy mechinary over unprotected soils will be negative and moderate.
		Cumulative	2	3	3	4	2.1 - MOD		Mining and the utilisation of heavy mechanery on unprotected soils will result in loss of resource due to compaction.
		Residual	2	3	2	4	1.9 - LOW		Well managed mining plan the control of vehicle movements to specific pathways (access routes and haulage ways) will reduce the overall impact.
	Loss of soil and land capability due to reduction in nutrient status - de-nutrification and leaching due to stripping and stockpiling of resource	Existing	2	3	3	5	2.7 - MOD	Strip soils with vegetative cover in tacked, stockpile utilisable soils seperately from subsoils and soft overburden, restrict stockpiles and berms to less than 1,5m high for utilisable soil and 15m for the soft overburden, vegetate stores of soil and overburden and manage ingress of dirty water and erosion.	Soil nutrient status is ambient and of a naturally poor status due to natural chemistry of sediments from which soils are formed. Land capability is at best low intensity grazing land.
		Cumulative	2	3	3	5	2.7 - MOD		Stripping and stockpiling of soils will result in additional loss of nutrient status, albeit that the inclusion of vegetative matter will assist in retention of seed pool.
		Residual	2	3	2	4	1.9 - LOW		Well managed and well protected soil stockpiles will reduce the de-nitrification and loss of nutrient stores from the stockpiles

5.2.2 Operational Phase

Issue ***Loss of utilisable resource (Sterilization and erosion), compaction, de-nutrification and contamination or salinization.***

The operation of the Ash Disposal Facility development (deposition of ash, management of water and associated activities) will see the impact of the transportation of materials into and out of the waste site (ash and water in, water out), the potential for spillage and contamination of the in-situ and stockpiled materials, contamination due to dirty water run-off and/or contaminated dust deposition/dispersion, the de-nutrification of the stockpiled soils due to excessive through flow and the leaching out of nutrients and metals due to rain water on unconsolidated and poorly protected soils, and, the potential for compaction of the in-situ materials by uncontrolled vehicle movement and the loss to the environment (down-wind and downstream) of soil by wind and water erosion over un-protected ground.

In summary, the operation will potentially result in:

- The sterilisation of the soil resource on which the facilities are constructed. This will be an on-going loss for the duration of the operation and beyond;
- The creation of dust and the possible loss (erosion) of utilisable soil down-wind and/or downstream, and the potential for contamination of the soils from dust fallout and overland flow of dirty water;
- The compaction of the in-situ and stored soils and the potential loss of utilisable materials from the system;
- The contamination of the soils by dirty water run-off and or spillage of hydrocarbons from vehicle and machinery or from dust and emissions from the process;
- Contamination of soils by use of dirty water for road wetting (dust suppression) and irrigation of the stockpile vegetation;
- Potential contamination of soils by chemical spills of reagents being transported to site;
- Sterilisation and loss of soil nutrient pool, organic carbon stores and fertility of stored soils;
- Impact on soil structure and soil water balance.

Un-managed soil stockpiles and soil that is left uncovered/unprotected will be lost to wind and water erosion, will lose the all-important, albeit moderately poor nutrient content and organic carbon stores (fertility), and will be prone to compaction.

A positive impact will be the rehabilitation of the temporary infrastructure used during the start-up and construction phase.

Impact Significance

In the un-managed scenario these activities will **probably** result in a MODERATE to HIGH negative significance that will affect the *development footprint and adjacent* sites for the medium to long term. These effects are *very* likely to occur.

It is inevitable that some of the soils will be lost during the operational phase if they are not well managed and a mitigation plan is not made part of the general management schedule.

The impacts on the soils during the operational phase (stockpiled, peripheral soils and downstream (wind and water) materials) may be mitigated with well initiated management procedures.

These should include:

- Minimisation of the area that can potentially be impacted (eroded, compacted, sterilised or de-nutrified);
- Timeous replacement of the soils so as to minimise/reduce the area of affect and disturbance;
- Effective soil cover and adequate protection from wind (dust) and dirty water contamination – vegetate and/or rock cladding;
- Regular servicing of all vehicles in well-constructed and bunded areas;
- Regular cleaning and maintenance of all haulage ways, conveyencing routes and service ways, drains and storm water control facilities;
- Containment and management of spillage;
- Soil replacement and the preparation of a seed bed to facilitate and accelerate the re-vegetation program and to limit potential erosion on all areas that become available for rehabilitation (temporary servitudes), and
- Soil amelioration (rehabilitated and stockpiled) to enhance the growth capability of the soils and sustain the soils ability to retain oxygen and nutrients, thus sustaining vegetative material during the storage stage.

It will be necessary as part of the development plan to maintain the integrity of the stored soils so that they are available for rehabilitation at decommissioning and closure. If the soil quantities and qualities (utilisable soils) are managed well throughout the operational phase, rehabilitation costs will be reduced and natural attenuation will more easily and readily take effect. This will result in a more sustainable "End Land Use" being achieved.

Residual Impact

In the *long term* (Life of the operation and beyond) and if implemented correctly, the above mitigation measures will **probably** reduce the negative impact on the utilisable soil reserves (erosion, contamination, sterilization) to a significance rating of MODERATE LOW in the medium term, and is *very likely* to occur.

However, if the soils are not retained/stored and managed, and a workable management plan is not implemented the residual impact will definitely incur additional costs and result in the impacting of secondary areas (Borrow Pits etc.) in order to obtain cover materials etc.

Table 5.2.2 Operational Phase – Impact Significance

OPERATIONAL PHASE									
Activity	**Description of Impact**	**Impact type**	**Spatial Scale**	**Duration**	**Significance**	**Probability**	**Rating**	**Mitigation Measures**	**Interpretation**
Primarily storage and management of soil resource during the operation of the ADF for thr life of the project.	Continued loss of soil resource and utilisation potential over infrastructural sites and operational areas	Existing	3	3	4	5	3.3 - HIGH	Restrict area of impact to as small an area as practical and manage stockpiles for erosion by wind and water.	Unprotected soils and material stockpiles will be lost to wind and water erosion
		Cumulative	2	3	4	4	2.4 - MOD		Little or no cumulative effects will be imparted to the soils or affect the land capability during the operational phase.
		Residual	2	3	2	4	1.9 - LOW		Well protected soil stockpiles and in-situ materials will be more easily retained and available for rehabilitation at closure
	Loss of resource due to unprotected overland flow of water (suspended solids) and erosion of soil due to wind - potential off site dust issues	Existing	3	4	3	5	3.3 - HIGH	Manage stockplies and berms. Control vegetative cover and ingress of dirty water. Maintain stormwater control system and erosion due to unprotected soil cover.	Unprotected soils and material stockpiles will be lost to wind and water erosion
		Cumulative	2	3	4	4	2.4 - MOD		Little or no cumulative effects will be imparted to the soils or affect the land capability during the operational phase.
		Residual	2	3	2	4	1.9 - LOW		Well protected soil stockpiles and in-situ materials will be more easily retained and available for rehabilitation at closure
	Continued loss of soil utilisation due to contamination from spillage of waste, reagents and hydrocarbons from vehicles and mechanised infrastructure and from storage facilities (soil stockpiles).	Existing	3	3	3	5	3 - MOD	On-going management and control of vehicle maintenance, movements and cover to loads of raw materials. Spillage from haulage ways and vehicles to be claened regularly and placed back into the processing system.	Unmanaged and uncontrolled spillage and lack of vehicle maintenance will negativily impact of soils, while dirty water resulting from spillage of raw materials and/or hydrocarbons will impact the stockpiles and soil storage facilities negativily.
		Cumulative	2	3	2	4	1.9 - LOW		Little or no cumulative effects will be imparted to the soils or affect the land capability during the operational phase.
		Residual	2	3	2	4	1.9 - LOW		Well managed and controlled vehicle maintenance and spillage control from haulage vehicles or conveyer lines will assist in controlling the negative impacts of contamination of the soils.
	Loss of soil utilisation potential due to operation of conveyers and site mechaniery, stormwater controls (pumps etc.) and the loss of nutrient stores and organic carbon from unprotected stockpiles and in-situ contamination on sites.	Existing	3	3	3	5	3 - MOD	Maintenance of cover (vegetative or rock) to stockpiles and berm storage piles, cultivation and enplacement of stormwater and erosion control features and restriction of ingress of dirty water.	Unmanaged and uncontrolled spillage and lack of vehicle maintenance will negativily impact of soils, while dirty water resulting from spillage of raw materials and/or hydrocarbons will impact the stockpiles and soil storage facilities negativily and render the soils un-usable for rehabilitation and closure.
		Cumulative	2	3	2	4	1.9 - LOW		Little or no cumulative effects will be imparted to the soils or affect the land capability during the operational phase.
		Residual	2	3	2	4	1.9 - LOW		Well managed and controlled vehicle maintenance and spillage control from haulage vehicles or conveyer lines will assist in controlling the negative impacts of contamination of the soils either directly or through dirty water movement over unprotected soil.

5.2.3 Decommissioning & Closure Phase

Issue: Net loss of soil volumes and utilisation potential due to change in material status (Physical and Chemical) and loss of nutrient base.

The impacts on the soil resource during the decommissioning and closure phase have both a positive and a negative effect, with:

- The loss of the soils original nutrient status and store and the reduction in the already low organic carbon by leaching of the soils while in storage;
- Erosion and de-oxygenation of materials while stockpiled;
- Compaction and dust contamination due to vehicle movement and wind impacts on the soil while rehabilitating the area;
- Erosion of soils during slope stabilisation and re-vegetation of disturbed areas;
- Contamination of replaced soils by use of dirty water for plant watering and dust suppression on roadways;
- Hydrocarbon or chemical spillage from contractor and supply vehicles;
- Positive impacts of reduction in areas of disturbance and return of soil utilisation potential, uncovering of areas of storage and rehabilitation of compacted materials.

Impact Significance

The impact will **probably** remain the net loss of the soil resource if no intervention or mitigating strategy is implemented. The intensity potential will remain MODERATE to LOW and positive for the medium to short term for all of the activities if there is no active management (rehabilitation and intervention) in the decommissioning phase, and closure will not be possible. The impacts will be confined to the *development* area and its *adjacent* buffer, and is *likely* to happen.

This will result in an irreversible impact that is continuous.

However, with interventions and well planned management, there will be a MODERATE to HIGH positive intensity potential as the soils are replaced and fertilization of the soils is implemented after removal of the infrastructure.

Ongoing rehabilitation during the operational and decommissioning phases will bring about a net long-term positive impact on the soils, albeit that the land capability will likely be reduced to grazing status.

The intensity potential of the initial activities during rehabilitation and closure will be moderate and negative due to the necessity for vehicle movement while removing the demolished infrastructure and rehabilitating the operational footprints. Dust will **potentially** be generated and soil will **probably** be contaminated, compacted and eroded to differing extents depending on the degree of management implemented.

The positive impacts of rehabilitation on the area are the reduction in the footprint of disturbance, the amelioration of the affected soils and oxygenation of the growing medium, the stabilizing of slopes and the revegetation of disturbed areas.

Residual Impacts

On closure of the mining operation the *long-term* negative impact on the soils will be reduced from a significance ranking of MODERATE to LOW if the management plan set out in the Environmental Management Plan is effectively implemented. These impacts will be confined to the development site and its adjacent environments, and is *very likely* to occur.

Chemical amelioration of the soils will have a low but positive impact on the nutrient status (only) of the soils in the medium term.

At closure (obtaining of certificate of closure from authorities) the residual impact should, if all rehabilitation and management efforts have been complied with, result in a positive impact, with the area being returned to a land capability of low intensity grazing or wilderness status, and the use of the land being returned to that of livestock management.

Table 5.2.3a Decommissioning, Closure and Rehabilitation Phase – Impact Significance

CLOSURE AND POST-CLOSURE PHASE									
Activity	**Description of Impact**	**Impact type**	**Spatial Scale**	**Duration**	**Significance**	**Probability**	**Rating**	**Mitigation Measures**	**Interpretation**
Rehabilitation and Closure of the Ash Disposal facility and Associated Infrastructure	Loss of soil nutrient store and organic carbon stores while in storage and while being replaced onto rehabilitated areas - leaching of unprotected materials	Existing	2	4	3	5	3 - MOD	Replacement of nutrient and organic carbon needs and requirements at time of rehabilitation, landscaping of the topographic slope, cultivation of soils and replacement of vegetative cover as soon after replacement of materials as possible. Monitoring of vegetative growth until self sustaining.	The loss of soil nutrient while in storage will need to be replaced. If not adequately accounted for the soils will be restrictive on rehabilitation success.
		Cumulative	2	4	3	5	3 - MOD		On-going loss of nutrient during the replacement phase will result in negative impacts and poor vegetative cover with resultant erosion of resource.
		Residual	2	3	2	3	1.4 - LOW		Well managed and monitored reinplacement of soils along with additives based on sound analytical results will result in a lowering of the impact and a net improvement in the rehabilitated product.
	Contamination of in-situ and stored materials by dirty water outwash and use of dirty water for irrigation of rehabilitated sites	Existing	3	3	3	5	3 - MOD	Management of stormwater control system, and monitoring of water quality used for watering/irrigation of vegetated areas.	Utilisation of poor quality water on rehabilitated soils and/or stockpiles will result in contamination of materials and negative impacts on soil water and possibly the groundwater as well.
		Cumulative	3	3	3	5	3 - MOD		There will be little or no cumulative effects during the closure phase.
		Residual	3	3	2	4	2.1 - MOD		Well managed reinstatement of the soils in the correct sequence and the irrigation of the re-instated vegeative cover with good quality water (SAWQG) will result in a low positive significance rating.
	Hydrocarbon spills from rehabilitation equipment plus potential for compaction of replaced materials, erosion from water and dust and impacts on off site streams and rivers (sedimentary load)	Existing	3	3	3	5	3 - MOD	Maintenance and management of all vehicles, and restrictions on access of vehicles and animals/humans to rehabilitated areas and unprotected soil. Installation of erosion control measures along all drainage ways or water channels.	Utilisation of poorly serviced and maintained vehicles and poor quality water on rehabilitated soils and/or stockpiles will result in contamination of materials and negative impacts on soil and their capability to sustain a vegetative cover. This will in turn result in the loss of soil from the system due to erosion.
		Cumulative	3	3	3	5	3 - MOD		There will be little or no cumulative effects during the closure phase.
		Residual	3	2	2	4	1.9 - LOW		Well managed and maintenance of vehicles and the use of good quality irrigation water on re-instated vegeative cover will result in a low but positive significance rating.
	Addition of fertiliser and composite with potential for contamination to vadose zone and soil water	Existing	3	2	3	3	1.6 - LOW	Assesssmnet of soil requiremets and water holding capabilities and calculation of fertiser requirements as part of rehabilitation planning and implementation programme. Monitoring of water quality at closest waterway.	Over fertilisation of soils and the addition of additives in uncontroolled and monitored manner will impact the soils and soil water negativily.
		Cumulative	3	2	3	3	1.6 - LOW		There will be little or no cumulative effects during the closure phase.
		Residual	3	2	2	4	1.9 - LOW		Small amounts of fertiliser and soil additives on a more frequent basis will result in the uptake of the additions by the vegetation and the maintenance of good quality soil water.
	Uncontrolled access to rehabilitated sites by animal, people and vehicles - compaction and erosion due to loss of vegetative cover (over grazing etc.)	Existing	3	2	3	4	2.1 - MOD	Control of access using fencing and controlled/manned gate entrances.	Uncontrolled acces of vehicles, animals and people will result in the loss of vegetative cover and the loss of the soil cover to erosion by wind and water.
		Cumulative	3	2	3	4	2.1 - MOD		There will be little or no cumulative effects during the closure phase.
		Residual	3	2	2	4	1.9 - LOW		Controlling of access to the rehabilitated sites and ADF will give the vegetation time to establish and form a natural cover to the soils. This will have a net positive impact on the soils and their capability to sustain cover.

6. ENVIRONMENTAL MANAGEMENT PLAN

6.1 General

In accordance with the International Principles (IFC Performance Principles), and the concept of sustainability, it is incumbent on any developer to not only assess and understand the possible impacts that a development might cause, but to also propose and table management measures that will aid in minimising and where possible mitigate the effects.

The management of the natural resources (soils) have been assessed on a phased basis (construction, operation and decommissioning/closure) in keeping with the impact assessment (EIA) philosophy, while the Environmental Management Plan (EMP) has been designed as a working plan and utilisable guide for soil and land management.

The results tabled are based on the site specifics of geomorphology (topography, altitude, attitude, climate and ground roughness) and the activities as described in the project design criteria as the basis for the impact assessment and the effects on the environment.

The plan gives recommendations on the stripping and handling of the soils throughout the life of the development along with recommendations for the utilization of the soils for rehabilitation at closure.

It has been assumed that all infrastructure will be removed and that the areas that were affected will be returned to as close as possible their pre-construction state (topographic levels, wilderness/conservation or low intensity grazing status – Refer to the Chamber of Mines Land Classification System (Refer to Section 2 - Table 2.2.1 of the Baseline Study), albeit that an Ash Disposal Facility will inevitably remain as a permanent feature.

The concept of stripping and storage of all “Utilisable” soil is recommended as a minimum requirement and as part of the overall Soil Utilisation Philosophy.

In terms of the “Minimum Requirements”, **usable or utilisable soil** is defined here as all soil above an agreed subterranean cut-off depth defined by the project soil scientist, and will vary for different forms of soil encountered in a project area and the type of project being considered. It does not differentiate between topsoil (orthic horizon) and other subsoil horizons necessarily.

The following soil utilisation guidelines **(*all be they generic*)** should be incorporated into the management plan wherever possible:

- Over areas of deep excavation *strip all usable soil* as defined (700mm) in terms of the soil classification and stockpile as berms or low, terraced stockpiles. Alluvial soils should be stockpiled separately from the colluvial (shallower) and in-situ derived materials, which in turn should be stored separately from any calcrete/ferricrete material, while the soft overburden is stored as a separate unit and as a defined stockpiles of less than 15m in height preferably. Protect from contamination and erosion by rock cladding or vegetation cover and adequate drainage of surface runoff.

At *rehabilitation* replace the soft overburden followed by the calcrete/ferricrete, compact and replace the soil to appropriate soil depths, and cover areas to achieve an appropriate topographic aspect and attitude that will achieve a free draining landscape as close as possible to the pre-mining/construction land capability rating.

- Over areas planned for less invasive Structures (Offices, Workshops etc) and any material stockpile or storage, *strip the top 500 mm* of usable soil over all affected areas including terraces and *strip remaining usable soil and calcrete (if present in profile)* where founding conditions require further soil removal.

  Store the soil in stockpiles or berms of not more than 1.5 m around infrastructure area ready for closure rehabilitation purposes. Stockpile hydromorphic (wet) soils separately from the dry materials, and the "calcrete" separately from all other materials.

  Protect all stockpiles from water and wind erosion (loss of materials) and contamination by dust and runoff water. Clad stockpiles with larger rock or vegetate the stored materials.

  At closure/rehabilitation, remove all large boulders and gravel from the rehabilitated landscape and place at the base/bottom of the foundations or open pit profile so that they do not interfere with the tillage and cultivation of the final surface. Remove foundations to a maximum depth of 1m. Replace soil to appropriate soil depths, and over disturbed areas and in appropriate topographic position to achieve pre-development land capability and land form where possible.

- Over areas of Tailings Storage facilities, Ash Disposal Facilities, Waste Rock Dumps and all Heavy Vehicle Haulage Roads and Major Access Routes, *strip usable soil* to a *depth of 750 mm where possible and/or* in areas of *arable soils,* and *between 300mm and 500mm* in areas of *soils with grazing land capability.* Stockpile hydromorphic soils separately from the dry and friable materials.

  Before *rehabilitation* remove all gravel and other rocky material and recycle as construction material or place in open voids. Remove foundations to a maximum depth of 1m. Replace soil to appropriate soil depths and in appropriate topographic position so as to achieve pre-mining land capability. Protect the stored materials from erosion and contamination using vegetation or rock cladding.

- Over areas to be utilized for General Access Roads (light delivery vehicles), Laydown Pads and any Conveyencing servitudes (Above ground pipelines and power line servitudes) *strip the top 150 mm* of usable soil over all affected areas and stockpile in longitudinal stockpile or berms upslope of the facilities. Protect from erosion and contamination.

6.2 Construction Phase

The construction methods to be used and the final End Land Use (ELU) at rehabilitation and closure are important in deciding how the utilisable soils need to be stripped and retained, and ultimately how much of the materials will be needed for the rehabilitation (stripping volumes).

Failure to remove and store the utilisable materials will result in the permanent loss of the growth medium.

Making provision for retention of utilisable material for the decommissioning and/or during rehabilitation will not only save significant costs at closure, but will ensure that additional impacts to the environment do not occur.

The depths of utilisable materials on Site “H” vary between 300mm and greater than 1,200mm.

Due to the shallow soil depths on the more rocky areas it is recommended that sufficient materials are removed from the areas were significant soil depths are present and do exist, so that the shallow areas can be adequately resorted during rehabilitation and at closure.

For the ADF footprint as a whole, and the nature of the activities that will take place as support infrastructure to the ash disposal it is recommended that at least 750mm of soil should be removed/stripped wherever possible.

The conveyencing route and access roads/ways will require that only 500mm of soil is removed and stored.

The areas confirmed as low sensitivity and or outside of the No Go zones are sufficiently similar that they can be stored as one soil group (Refer to Figure 5 – Soil Sensitivity Map). However, the Highly Sensitive and “No Go” areas (wetland areas) should not be impacted unless absolutely necessary, and then only if the necessary permissions have been obtained (licenses etc.).

Table 6.2 is a plan for soil utilisation during the construction phase.

Table 6.2 — Construction Phase – Soil Utilisation Plan

Phase	Step	Factors to Consider	Comments
Construction	Delineation of areas to be stripped		Stripping will only occur where soils are to be disturbed by activities that are described in the design report, and where a clearly defined end rehabilitation use for the stripped soil has been identified.
	Reference to biodiversity action plan		It is recommened that all vegetation is stripped and stored as part of the utilizable soil. However, the requirements for moving and preserving fauna and flora according to the biodiversity action plan should be consulted.
	Stripping and Handling of soils	Handling	Soils will be handled in dry weather conditions so as to cause as little compaction as possible. Utilisable soil (Topsoil and upper portion of subsoil B2/1) must be removed and stockpiled separately from the lower "B" horizon, with the ferricrete layer being seperated from the soft/decomposed rock, and wet based soils seperated from the dry soils if they are to be impacted.
		Stripping	The "Utilizable" soil will be stripped to a depth of 750mm or until hard rock/ferricrete is encountered. These soils will be stockpiled together with any vegetation cover present (only large vegetation to be removed prior to stripping). The total stripped depth should be 750mm, wherever possible.
	Delineation of Stockpiling areas	Location	Stockpiling areas will be identified in close proximity to the source of the soil to limit handling and to promote reuse of soils in the correct areas. All stockpiles will be founded on stabilized and well engineered "pads"
		Designation of Areas	Soils stockpiles will be demarcated, and clearly marked to identify both the soil type and the intended area of rehabilitation.

This "Soil Utilisation Plan" is intimately linked to the "development plan", and it should be understood that if the plan of construction changes, these recommendations will probably have to change as well.

6.3 Operational Phase

The operational phase will see very little change in the development requirements, with the footprint of disturbance remaining constant, albeit that the temporary infrastructure might become redundant and rehabilitation of these features might be possible.

Maintenance and care of the soil and land resources will be the main management activity and objective required during the operational phase. Management of material loss, compaction and contamination are the main issues of consideration. Table 6.3 give details and recommendations for the care and maintenance of the resource during the operational phase.

The semi-arid climate and unique character of the soils in the study area require that the site specific and unique natural phenomena should be used to the advantage of the project.

Working with or on the differing soil materials (all of which occur within the areas that are to be disturbed) will require better than average management and careful planning if rehabilitation is to be successful, and it is important that the sensitive and highly sensitive materials are avoided wherever possible.

Care in removal and stockpiling/storage of the "Utilisable" soils, and protection of materials which are derived from the wet based soil is imperative to the success of sustainable rehabilitation in these areas, with the soil water (near surface water) held within the profile by this inhibiting layer being of great importance and integral to the success of the biodiversity and ecological systems and services.

Table 6.3 Operational Phase – Soil Conservation Plan

Phase	Step	Factors to Consider	Comments
Operation	Stockpile management	Vegetation establishment and erosion control	Enhanced growth of vegetation on the Soil Stockpiles and berms will be promoted (e.g. by means of watering and/or fertilisation), or a system of rock cladding will be employed. The purpose of this exercise will be to protect the soils and combat erosion by water and wind.
		Storm Water Control	Stockpiles will be established/engineered with storm water diversion berms in place to prevent run off erosion.
		Stockpile Height and Slope Stability	Soil stockpile and berm heights will be restricted where possible to <2.0m so as to avoid compaction and damage to the soil seed pool. Where stockpiles higher than 1.5m cannot be avoided, these will be benched to a maximum height of 15m. Each bench should ideally be 1.5m high and 2m wide. For storage periods greater than 3 years, vegetative (vetiver hedges and native grass species - refer to Appendix 1) or rock cover will be essential, and should be encouraged using fertilization and induced seeding with water and/or the placement of waste rock. The stockpile side slopes should be stabilized at a slope of 1 in 6. This will promote vegetation growth and reduce run-off related erosion.
		Waste	Only inert waste rock material will be placed on the soil stockpiles if the vegetative growth is impractical or not viable (due to lack of water for irrigation etc.). This will aid in protecting the stockpiles from wind and water erosion until the natural vegetative cover can take effect.
		Vehicles	Equipment, human and animal movement on the soil stockpiles will be limited to avoid topsoil compaction and subsequent damage to the soils and seedbank.

6.4 Decommissioning and Closure

The decommissioning and closure phase will see:

- The removal of all infrastructure;
- The demolishing of all concrete slabs/plinths and the ripping of any hard/compacted surfaces;
- The backfilling of all voids and deep foundations and the reconstruction of the required barrier layer (compaction of ferricrete and clay rich materials) wherever feasible and engineering possible;
- Topdressing of the disturbed and backfilled areas with the stored “utilisable” soil ready for re-vegetation;
- Capping of the final phases of the disposal facility (ash disposal) and waste piles with utilisable soil;
- Vegetation of soil stockpiles and waste piles;
- Fertilisation and stabilisation of the backfilled and final cover materials (soil and vegetation) and
- The landscaping of the replaced soils to be free draining.

There will be a positive impact on the soil and land capability environments as the area of disturbance is reduced, the soils are returned to a state that can support low intensity wildlife grazing or sustainable conservation and the impacts of compaction and erosion are mitigated.

Table 6.4 is a summary of the proposed management and mitigation actions recommended.

Table 6.4 Decommissioning and Closure Phase – Soil Conservation Plan

Phase	Step	Factors to Consider	Comments
Decommissioning & Closure	Rehabilitation of Disturbed land & Restoration of Soil Utilization	Placement of Soils	Stockpiled soil will be used to rehabilitate disturbed sites either ongoing as disturbed areas become available for rehabilitation and/or at closure. The utilizable soil (500mm to 750mm) removed during the construction phase, must be redistributed in a manner that achieves an approximate uniform stable thickness consistent with the approved post development end land use (Conservation land capability and/or Low intensity grazing), and will attain a free draining surface profile. A minimum layer of 300mm of soil will be replaced.
		Fertilization	A representative sampling of the stripped and stockpiled soils will be analysed to determine the nutrient status and chemistry of the utilizable materials. As a minimum the following elements will be tested for: EC, CEC, pH, Ca, Mg, K, Na, P, Zn, Clay% and Organic Carbon. These elements provide the basis for determining the fertility of soil. based on the analysis, fertilisers will be applied if necessary.
		Erosion Control	Erosion control measures will be implemented to ensure that the soil is not washed away and that erosion gulleys do not develop prior to vegetation establishment.
	Pollution of Soils	In-situ Remediation	If soil (whether stockpiled or in its undisturbed natural state) is polluted, the first management priority is to treat the pollution by means of in situ bioremediation. The acceptability of this option must be verified by an appropriate soils expert and by the local water authority on a case by case basis, before it is implemented.
		Off site disposal of soils.	If in situ treatment is not possible or acceptable then the polluted soil must be classified according to the Minimum Requirements for the Handling, Classification and Disposal of Hazardous Waste (Local Dept of Water Affairs) and disposed of at an appropriate, permitted, off-site waste facility.

6.5 Monitoring and Maintenance

Nutrient requirements reported in this document are based on the monitoring and sampling of the soils at the time of the baseline survey. These values will definitely alter during the storage stage and will need to be re-evaluated before being used during rehabilitation

During the **rehabilitation exercise**, preliminary soil quality monitoring should be carried out to accurately determine the fertiliser and pH requirements that will be needed.

Additional soil sampling should also be carried out annually after rehabilitation has been completed and until the levels of nutrients, specifically magnesium, phosphorus and potassium, are at the required levels for sustainable growth.

Once the desired nutritional status has been achieved, it is recommended that the interval between sampling is increased. An annual environmental audit should be undertaken. If growth problems develop, ad hoc, sampling should be carried out to determine the problem.

Monitoring should always be carried out at the same time of the year and at least six weeks after the last application of fertilizer.

Soils should be sampled and analysed for the following parameters:

pH (H_2O)	Phosphorus (Bray I)	
Electrical conductivity	Calcium mg/kg	
Cation exchange capacity	Sodium mg/kg;	
Magnesium mg/kg;	Potassium mg/kg	Zinc mg/kg;
Clay, sand and Silt	Organic matter content (C %)	

The following maintenance is recommended:

- The area must be fenced, and all animals kept off the area until the vegetation is self-sustaining;
- Newly seeded/planted areas must be protected against compaction and erosion (Vetiver hedges etc.);
- Traffic should be limited were possible while the vegetation is establishing itself;
- Plants should be watered and weeded as required on a regular and managed basis were possible and practical;
- Check for pests and diseases at least once every two weeks and treat if necessary;
- Replace unhealthy or dead plant material;
- Fertilise, hydro seeded and grassed areas soon after germination, and
- Repair any damage caused by erosion;

LIST OF REFERENCES

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Van der Watt, H.v.H and Van Rooyen T. H, 1990. A glossary of soil science, Pretoria: Soil Science Society of South Africa (1990).

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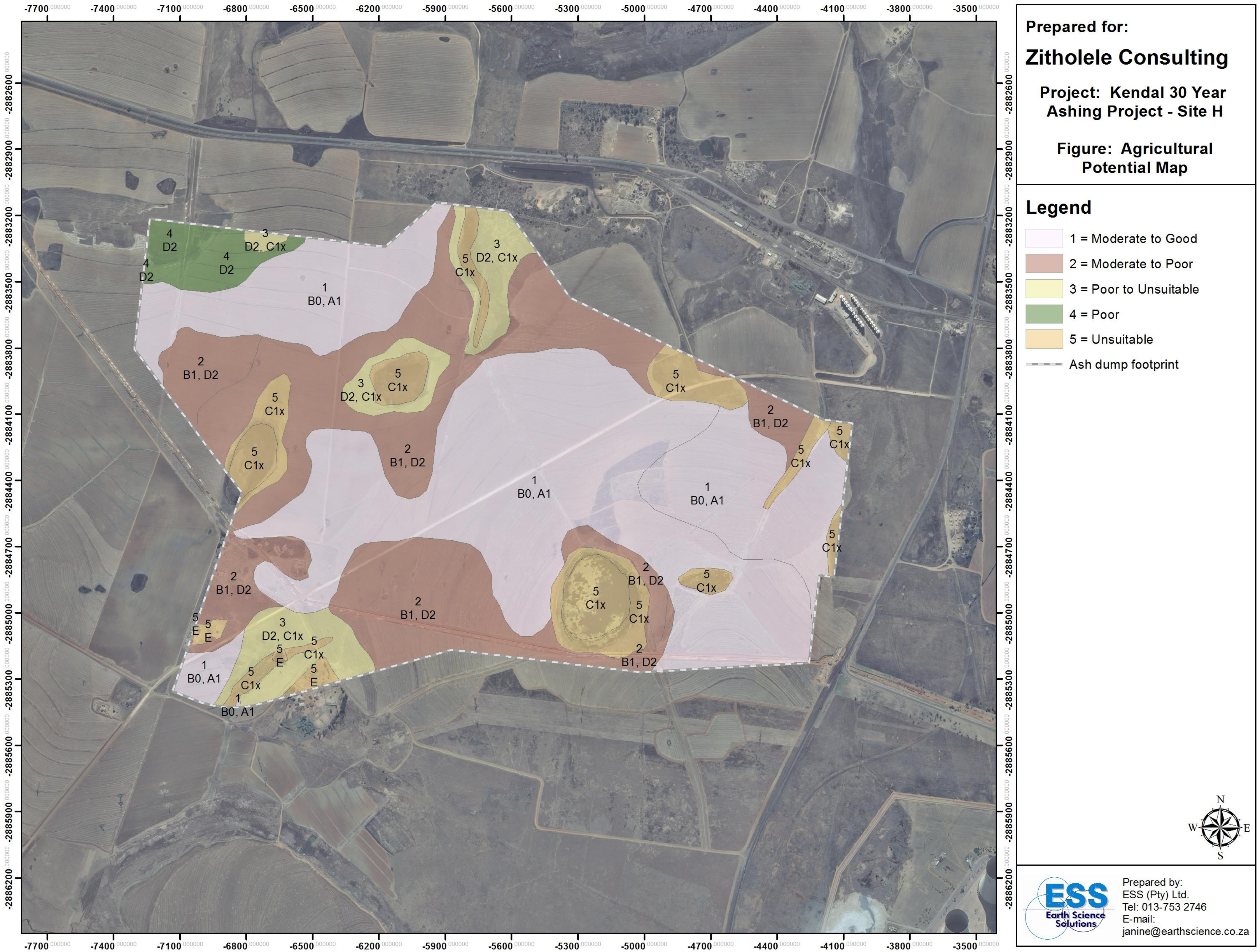
APPENDIX 1

SITE MAPS A3)
(Soils, Soil Groups and Land Capability)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Zitholele Consulting
Project: Kendal 30 Year Ashing Project - Site H
Figure: Agricultural Potential Map
Legend
1 = Moderate to Good
2 = Moderate to Poor
3 = Poor to Unsuitable
4 = Poor
5 = Unsuitable
Ash dump footprint
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E
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ESS
Earth Science Solutions
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B0, A1
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B1, D2
3
D2, C1x
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C1x
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-7400
-7100
-6800
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-6200
-5900
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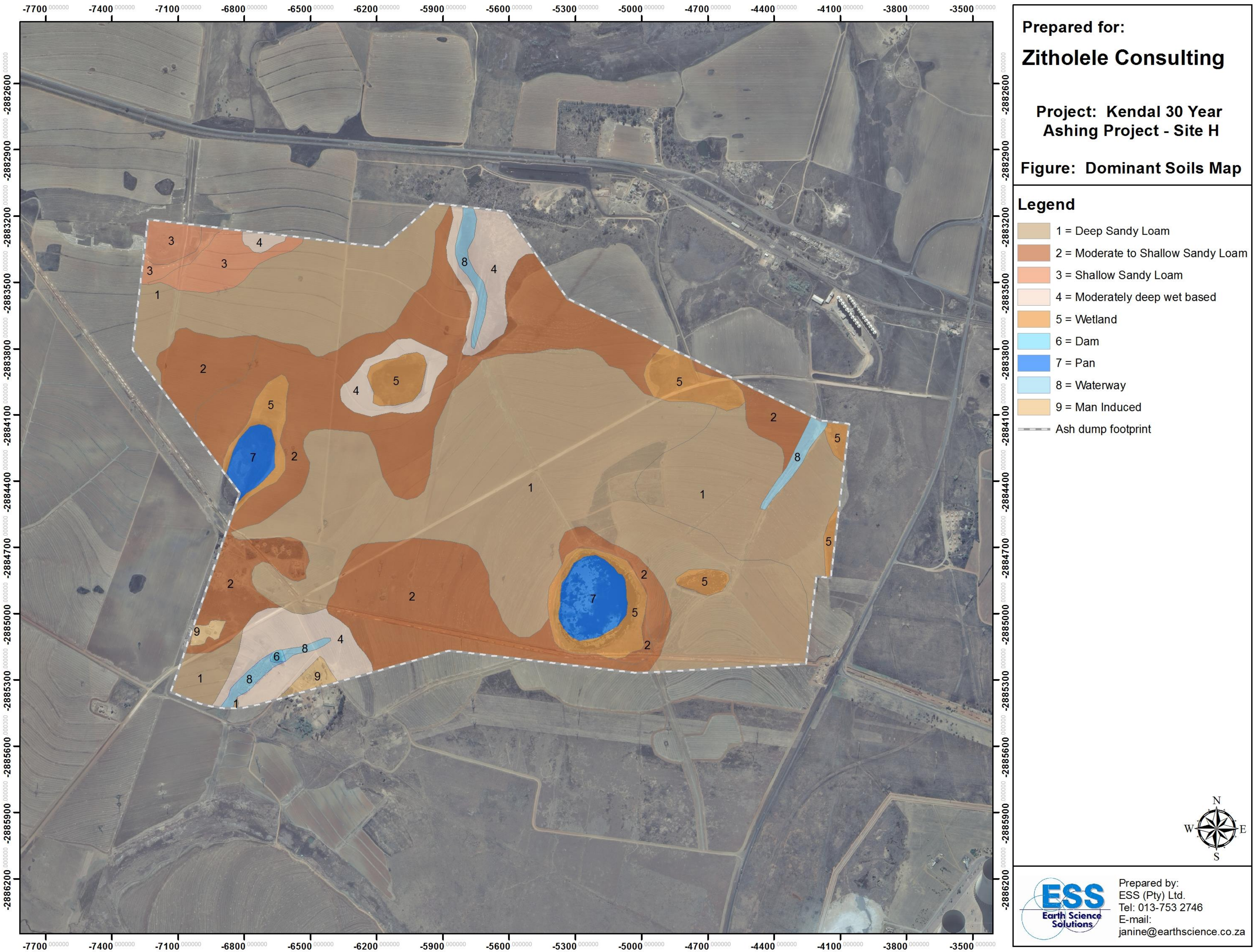
Prepared for:
Zitholele Consulting
Project: Kendal 30 Year Ashing Project - Site H
Figure: Dominant Soils Map
Legend
1 = Deep Sandy Loam
2 = Moderate to Shallow Sandy Loam
3 = Shallow Sandy Loam
4 = Moderately deep wet based
5 = Wetland
6 = Dam
7 = Pan
8 = Waterway
9 = Man Induced
Ash dump footprint
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ESS
Earth Science Solutions
Prepared by:
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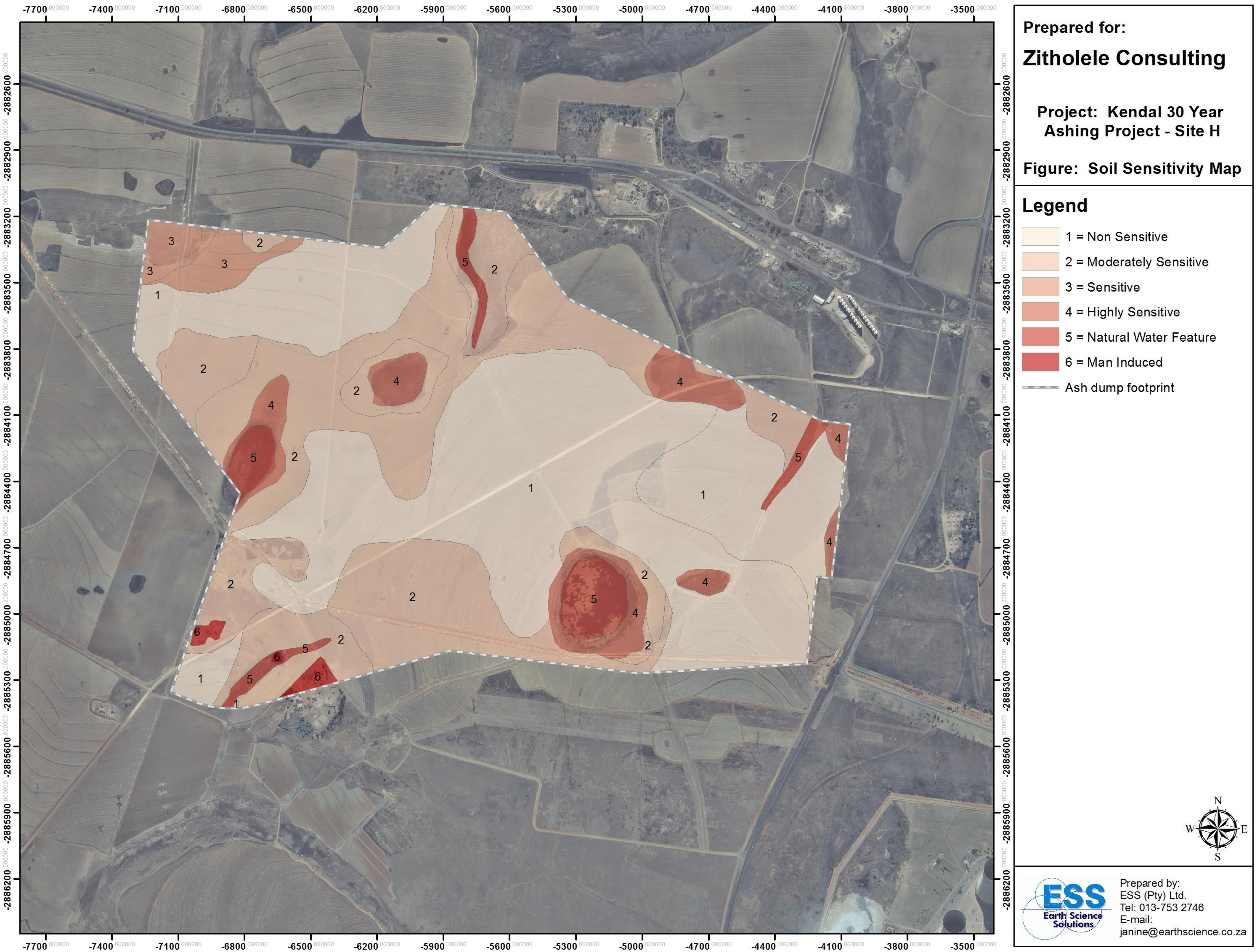
Prepared for:
Zitholele Consulting
Project: Kendal 30 Year Ashing Project - Site H
Figure: Soil Sensitivity Map
Legend
1 = Non Sensitive
2 = Moderately Sensitive
3 = Sensitive
4 = Highly Sensitive
5 = Natural Water Feature
6 = Man Induced
Ash dump footprint
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APPENDIX 2

VETIVER GRASS

THE VETIVER SYSTEM
A PROVEN SOLUTION
The Vetiver Network International - www.vetiver.org

VETIVER GRASS
A HEDGE AGAINST EROSION
The Vetiver Network International - www.vetiver.org

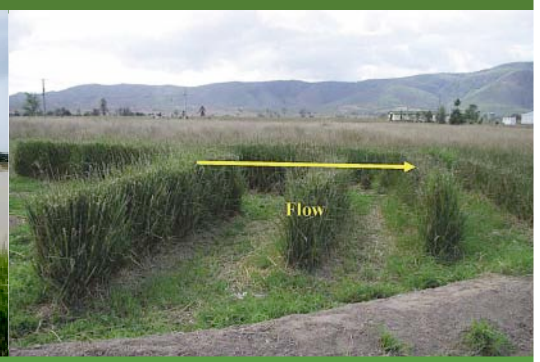

Malaysia - highway stabilization


India - beach stabilization


Fiji - 2m high vetiver created terrace


Ethiopia - soil conservation


Cambodia - river bank stabilization



Australia - wastewater treatment

The problems we face are growing at a pace that challenges our ability to solve them
- Soil loss results in physical, chemical, and biological degradation and loss of ability to produce food.
- Land slides, unstable slopes and flooding destroy agricultural land and valuable infrastructure.
- Siltation of drains, lakes, reservoirs, and rivers reduce storage capacity and can result in flooding.
- Overuse and misuse of large areas of land, and contamination by toxic runoff from mine dumps, landfills, feedlots, salinization, etc.., require extensive reclamation programs.
- Water polluted by mineral or organic sediments as well as the pollutants mentioned above detrimentally affect drinking water supplies, fresh and saltwater fisheries, and coral reefs.
- Decreased groundwater recharge in watersheds results in local water shortages.
- Inattention to site stabilization and maintenance results in infrastructure failure and losses.

Solutions are often too complex or costly given existing resources and capacity
- The complexity and high cost of engineering and structural designs; ambitious and impracticable environmental protection and remedial practices - often due to over demanding design engineers and supervisors - and unnecessary high-end quality control measures; as well as, amongst others, bureaucratic accounting and bidding procedures.
- Low potential for sustainability due to lack of funds for maintenance, unsuitability to local conditions/ capacity, or need for continuous subsidies to maintain effectiveness.

Many of these problems share a common solution in THE VETIVER SYSTEM

The Vetiver System (VS)
- Consists of a simple vegetative barrier (a hedge) comprising upright, rigid, dense, and deeply-rooted clump grass, that slows runoff, allowing sediments to stay on site, eventually forming natural terraces.
- Vetiver grass is already found in more than 120 countries throughout the tropics and sub-tropics.
- It has been used for more than a century in many Asian, African, and Caribbean countries as a traditional "soil binding" technology.
- Today, the VS is used for soil and moisture conservation, bioengineering, and for bioremediation.

It is not weedy or invasive
- Hedges are propagated and established vegetatively. **Analyses show that recommended cultivars of *Chrysopogon zizanioides* (south India type) are sterile and are not invasive.**

Deep, tough roots
- Vetiver's deep, massive fibrous root system can reach down to two to three meters in the first year.
- This massive root system is likened to "*living nails*", binding the soil together.
- The measured maximum resistance of vetiver roots in soils is equivalent to one-sixth that of mild steel (75 Mpa); stronger than most tree roots; improves soil shear strength by as much as 39%
- The fibrous mat of roots strengthens earthen structures and removes many contaminants from soil and soil water.
- Closely planted slips grow into dense hedgerows with a deep, tough root systems. They can withstand inundation, and effectively reduce flow velocities, forming excellent filters that prevent soil loss.

THE PLANT -- VETIVER GRASS -- *Vetiveria zizanioides L (Nash) recently reclassified* ***Chrysopogon zizanioides L (Roberty)***


Chrysopogon zizanioides L (Roberty) previously named *Vetiveria zizanioides L (Nash)* common name: ***Vetiver Grass***


Planting slip


Tissue cultivation of vetiver grass


6 month vetiver root grown in Senegal


Cross section through a two year old hedgerow. Note sediment build up over original top soil (brown line)


Longitudinal section through hedgerow


Newly planted vetiver hedgerow

Large differences occur between the roots of vetiver grass species and cultivars. Compare *C. zizanioides* (upper) with *C. nemoralis* (lower)


Indian vetiver nursery of containerized plants


Planting containerized vetiver on steep highway fill slope in Malaysia


Vetiver inflorescence. In many cases vetiver never flowers, but when it does, it produces rather beautiful non-fertile flowers

WHY VETIVER GRASS
For a plant to be useful for agriculture and biological engineering, and be accepted as safe, it should have as many as possible of the following characteristics:
- Its seed should be sterile, and the plant should not spread by stolons or rhizomes, and therefore not escape and become a weed.
- Its crown should be below the surface so it can resist fire, over grazing, and trampling by livestock.
- It should be capable of forming a dense, ground level, permanent hedge, as an effective filter, preventing soil loss from runoff. Apparently only clones will grow 'into' each other to form such a hedge.
- It should be perennial and permanent, capable of surviving as a dense hedge for decades, but only growing where we plant it.
- It should have stiff erect stems that can, at minimum, withstand flowing water of 1 foot (30 cm) depth that is moving at 1 foot per second (0.3 meters/second).
- It should exhibit xerophytic and hydrophytic characteristics if it is to survive the extremes of nature. Vetiver grass, once established, is little affected and highly tolerant of droughts or floods.
- It should have a deep penetrating root system, capable of withstanding tunnelling and cracking characteristics of soils, and should the potential to penetrate vertically below the plant to at least three meters.
- It should be capable of growing in extreme soil types, regardless of nutrient status, pH, sodicity, acid sulphate or salinity, and toxic minerals. This includes sands, shales, gravels, mine tailings, and even more toxic soils.
- It should be capable of developing new roots from nodes when buried by trapped sediment, and continue to grow upward with the rising surface level, forming natural terraces.
- It should not compete with the crop plants it is protecting.
- it should not be a host (or intermediate host) for undesirable pests or diseases of any other plants.
- It should be capable of growing in a wide range of climates -- from 300 mm of rainfall to over 6,000 mm -- from air temperatures of -15º C (where the soil does not freeze) to more than 55º C. It should be able to withstand long and sustained droughts (>6 months).
- It should be cheap and easy to establish as a hedge and easily maintained by the user at little cost.
- It should be easily removed when no longer required.

Vetiver Grass cultivars used around the world for essential oil production, originating from south India, have all these characteristics.


Dense crown of a vetiver grass clump from which roots and shoots emerge


After a fire vetiver hedge remains vertical and quickly recovers with new growth


Erosion sediment trapped by a vetiver hedgerow in Madagascar.

Closely spaced (15 cm between plants at planting) hedgerow at left assures a properly dense hedge

Very dense and very effective vetiver hedgerow

VS FOR AGRICULTURE
- **On-farm** - in modern and traditional agriculture VS is used to trap sediments, control runoff, increase soil moisture recharge, and stabilize soils during intense rainfall and floods. There is only minimal competition with adjacent perennial and annual crops for moisture or nutrients. VS is used for wind erosion control, forage, and pest control.
- **On-farm** - VS protects rural structures such as roads, ponds, drains, canals and building sites. Also used for land and gully rehabilitation.
- **Off-farm** - VS plays a vital role in watershed protection at large scales - slowing down and spreading rainfall runoff, recharging groundwater reserves, reducing siltation of drainage systems, lakes and ponds, reducing agrochemical loading into groundwater and watercourses, and for rehabilitation of misused land.






Top left: Vetiver hedgerows protecting farm crops on steep slopes in the highlands of N.E. Thailand

Top center: Vetiver hedgerow on Darling Downs, Australia, used to reduce erosive power of flooding on flat land -- as a result more land can be cropped each year

Top right: Farmers from Gundalpet, India, have used vetiver for centuries to reduce soil loss, conserve moisture, provide forage, and increase groundwater recharge

Bottom left: Vetiver hedgerow used to protect crops from high winds in Pintang Island, China

Bottom center: Vetiver used to stabilize a farm road in Malaysia

Bottom right: A irrigation drain/canal stabilized by vetiver hedgerow

THE VETIVER SYSTEM
A PROVEN SOLUTION
The Vetiver Network International - www.vetiver.org

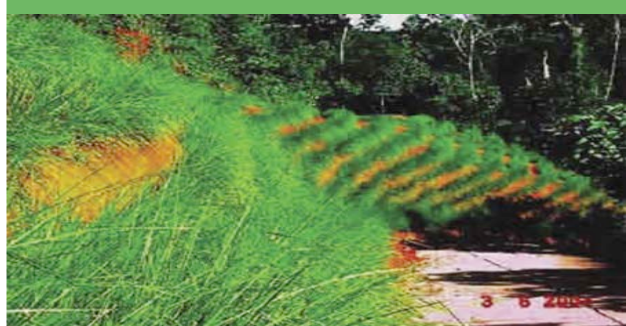
VETIVER GRASS
A HEDGE AGAINST EROSION
The Vetiver Network International - www.vetiver.org

VS FOR BIO-ENGINEERING

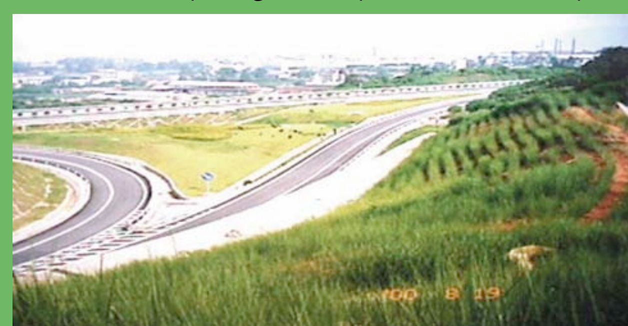
- For the stabilization and protection of infrastructure (roads, railroads, and building sites) VS is proven effective, efficient, and low cost when compared to other 'hard' engineering alternatives using cement, rock, and steel. Vetiver grass roots have an Mpa of 75 (1/6 the strength of mild steel) and will improve soil shear strength at a depth of 0.5 meters by as much as 39%. VS costs from 55% to 85% less than traditional engineering systems. **For successful applications cultivars of *Chrysopogon zizanioides* originally from south India should be used.** These cultivars are of the same genotype as Monto and Sunshine, and are **non-invasive.** They have a more massive root structure than non sterile *C.zizanioides* accessions from north India, Africa (*C.nigratana*) and Thailand (*C.nemoralis*)



The KEY to successful VS applications for infrastructure is the availability of large quantities of good quality vetiver planting material. Above, from left to right, are nurseries from Senegal (containerized), China (bare rooted) and Thailand (from in vitro plantlets)



Venezuela - rehabilitation of bauxite mine tailings. The soils are very acid and prone to slippage. High levels of fertilizer assure good growth



China - expressway stabilization. This cut was prone to massive slip. Stabilization with VS has given complete protection

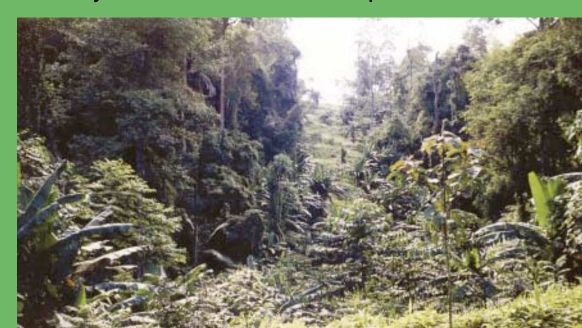
China - unstable highway fill prior to VS treatment. Road stability was so bad in untreated state that major lateral cracks in the pavement occurred

China - same fill less than a year later. After another two years this fill became fully forested. Untreated cut in background

Spain - unstable and eroding highway fill treated with VS. Untreated eroded fill on right. VS grows well under low rainfall Mediterranean climate

Vietnam: the Ho Chi Minh Highway has been stabilized with vetiver grass. The batters and fills are stable and withstand cyclonic rainfall events

Vietnam - Ho Chi Minh Highway - with and without vetiver stabilization



Thailand - a gas pipeline was laid through tropical forest. On steep slopes the right of way was stabilized with vetiver - native plants regenerated

Disaster mitigation - this railroad in Madagascar was closed down by frequent cyclone damage. Stabilization with vetiver was vital in its rehabilitation

Congo D.R. - huge gullies that destroy urban areas and houses can be rehabilitated and stabilized using the Vetiver System.

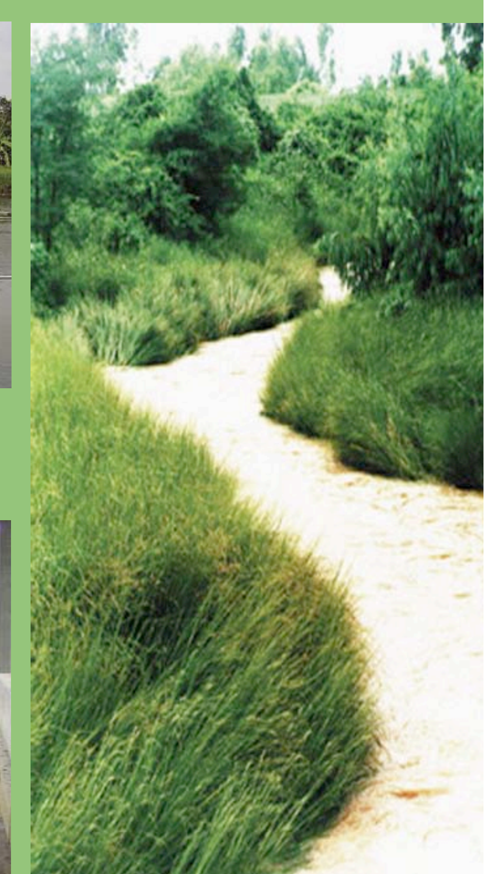
VS FOR WATER RELATED APPLICATIONS

- VS protects ponds, reservoirs, and rivers banks from erosion caused by wave action, it strengthens earthen dams against collapse, and it reduces maintenance costs and ensures the integrity of dam walls, canal and river banks, and drains.
- VS improves groundwater recharge through improved infiltration and reduced rainfall runoff, and the quality of water by removing sediments and chemicals.

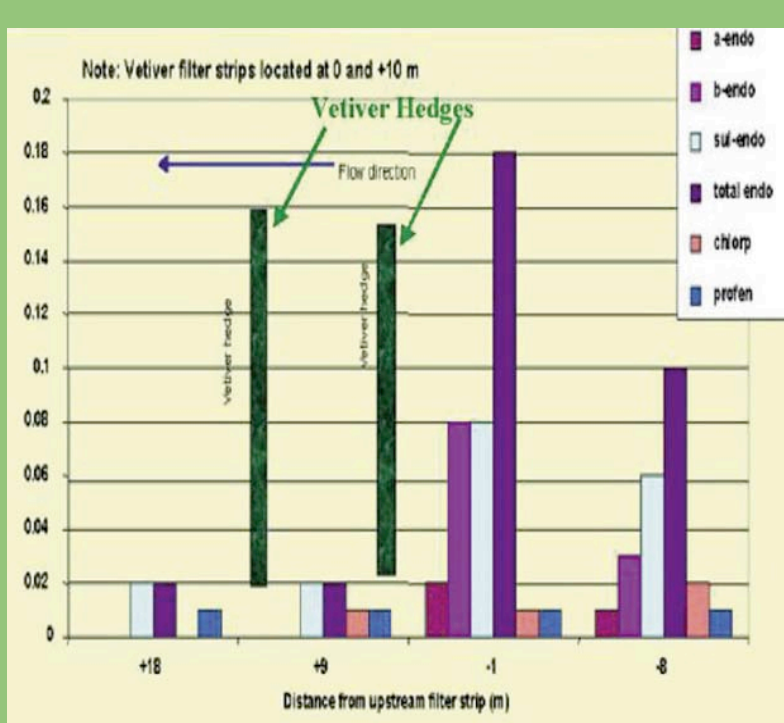
Venezuela - Vetiver withstands flooding for long periods. This grass was flooded for 8 months. Vetiver one month after flood receded

China - VS used to stabilize a small river bank located behind hedge allowing the safe production of crops

Vietnam - Vetiver is increasingly used to stabilize the banks of fishponds and to purify pond water



Zimbabwe - a fast flowing stream protected from stream bank erosion using VS application



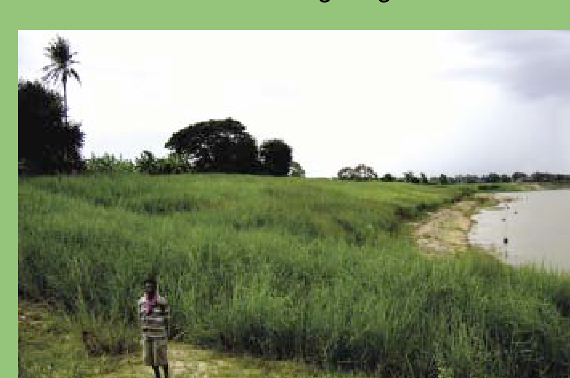
Australia - schematic of research results showing dramatic drop of pesticide levels as pesticide laden water moves through vetiver hedges from right to left. (Green columns = hedges - all other columns pesticide levels)

Australia - VS protects the right hand bank of a drain cut through acid sulphate soils of Queensland. Note left hand bank is devoid of any vegetation

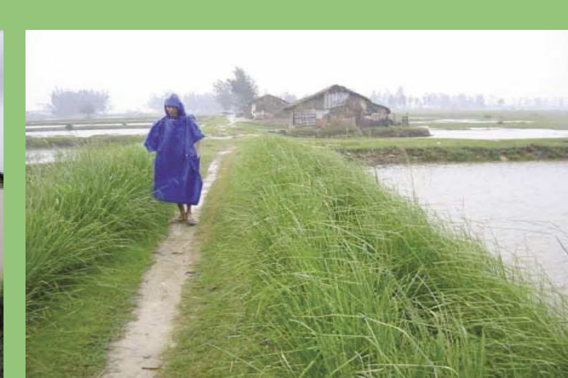
China - partially submerged vetiver grass used to stabilize the draw-down slope of a reservoir in Guangdong Province

Australia - this river bank and bridge abutment have been stabilized with vetiver. Vetiver is an excellent interface for concrete and soil

Cambodia - This very large bank on the Mekong River has been under continuous erosion. The land owner with assistance from TVNI is stabilizing using vetiver hedgerows.



Cambodia - the bank in the previous image has been reshaped and planted with vetiver hedgerows. Very good growth seven months after planting.



Vietnam - cyclone damage to sea dykes is a major problem. VS has been applied successfully for disaster mitigation

Vietnam - the left hand bank of the canal has been reshaped and stabilized with vetiver, the right bank has yet to be treated.

VS FOR BIO-REMEDIATION

- Onsite and offsite pollution control from wastes and contaminants is a breakthrough application of VS for environmental protection. Vetiver is being used to rehabilitate a large copper mine in China, coal mines in Indonesia, diamond mine spoils in South Africa, to control erosion and leachate from municipal landfills in China…. and more.
- Research has clearly established vetiver's tolerance to extremely high levels of Al, Mn, As, Cd, Cr, Ni, Cu, Pb, Hg, Se, and Zn.
- Vetiver has been used to reclaim soils and increase site productivity in places that were previously believed to be totally unproductive.

Vetiver grass will remove phosphate and nitrate from polluted water. The beaker on the left is before treatment; on the right 4 days later 90% P and 94% N removed

Australia - VS used as a buffer to absorb seeping sewage from this holiday camp site thus reducing runoff and smells

Australia - VS used to stabilize a gold slimes waste area. The hedges reduce the incidence of wind-blown, cyanide-polluted dust

Australia - VS used hydroponically on a pig effluent pond to reduce high levels of phosphate and nitrate

VS FOR OTHER USES

- In disaster mitigation and vulnerability reduction, VS has a crucial role to play…. "*The storms were terrible. [Afterward there were] landslides, roads destroyed, agricultural lands washed away; but, where there were vetiver barriers, everything seemed normal"*. (pers. comm. Mr. E. Mas, USDA/NRCS after Hurricane George, Puerto Rico)
- For handicrafts, perfumes, and medicinal purposes.
- For paper making, mulch, thatch, reinforcing bricks, biofuel, pest control, carbon sequestering, and many other uses.

Thailand - a selection of handicrafts, including handbags, vases, lamp shades, book covers, hats and other crafts from vetiver grass leaves and stems

Zimbabwe - a nicely thatched meeting house using vetiver grass thatch. The thatch will last three times as many years due to its resistance to insects and fungus attack

ACT NOW! **Contact TVNI for additional technical information.**

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Home Page: http//www.vetiver.org
Vetiver Clients Gallery: http://picasaweb.google.com/VetiverClients
Vetiver Picture Gallery:http://picasaweb.google.com/VetiverNetwork
Blog: http://vetivernetinternational.blogspot.com

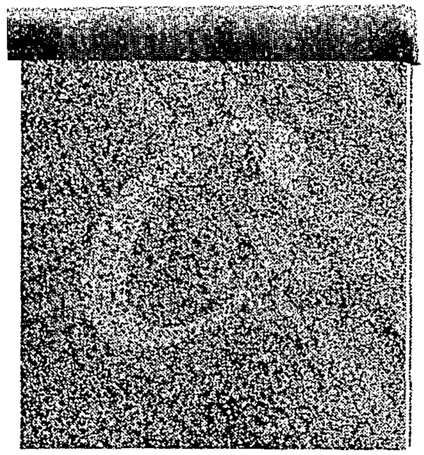
The Vetiver Network (TVNI) is a nonprofit foundation under United States code 501 (c) (3). It is a volunteer organization that promotes the use of the Vetiver System through dissemination of information and networking worldwide. TVN has helped established over 25 regional and country-based affiliated networks.

Contact your local vetiver network at:

FOR SUCCESSFULL VETIVER SYSTEMS APPLICATION ONLY USE CULTIVARS OF *CHRYSOPOGON ZIZANIOIDES* WITH CHARACTERISTICS OF SOUTH INDIAN GENOTYPES - SUCH AS SUNSHINE, MONTO, KARNATAKA, FIJI, MADUPATTY. THESE NOT ONLY HAVE GOOD ROOT SYSTEMS, BUT ARE KNOWN TO BE NON-INVASIVE AND ARE EXTENSIVELY RESEARCHED

APPENDIX 3

FERRICRETE CLASSIFICATION



Petrological and Geochemical Classification of Laterites

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Abstract

In this classification of lateritic covers four major types are distinguished: ferricretes, latosols, conakrytes and bauxites.

In ferricretes, hematite is associated with kaolinite, forming mottles, nodules and metanodules. When, at the top of profiles, goethite and sometimes gibbsite develop at the expense of hematite and kaolinite, protopisolitic and pisolitic dismantling facies are formed. Ferricretes, in which hematite and kaolinite form concretions, are widespread and are the most common iron accumulations.

Latosols are soft lateritic covers with a microglaebular structure. Red latosols, like ferricretes, are essentially formed by an association of hematite and kaolinite, but with larger proportions of goethite and with the presence of gibbsite.

Lateritic bauxites are concentrations of aluminium with which iron is very often associated. Four major types of lateritic bauxites: protobauxites, orthobauxites, metabauxites and cryptobauxites are defined as a function of the nature of iron and aluminium minerals as well as their relative distributions in profiles.

Protobauxites are lateritic soils where gibbsite and goethite form together under very humid climates. Orthobauxites are allites or alferrites, rich in gibbsite and red in colour, which do not exhibit a concretionary structure. Iron may be concentrated in hard caps called conakrytes and located close to the top of the bauxitic profiles. Conakrytes are reticular and non nodular ferrites or ferrallites in which hematite and goethite dominate and where gibbsite could be present in small proportions. The presence of kaolinite at the bottom of the profiles is not necessary. Metabauxites are boehmitic and show a concretionary or pisolitic structure; iron is dissociated from aluminium and is frequently concentrated as hematite in a kaolinitic ferricrete located at the bottom of the bauxitic profile. Kaolinite always appears at the bottom of metabauxite profiles and less frequently at the base of orthobauxites. In cryptobauxites, kaolinite is abundant at the top and at the bottom of the profiles so that the gibbsitic layer is embedded between two kaolinitic horizons.

This petrological and geochemical classification of laterites is based on reactions of hydration–dehydration and of silication–desilication regulated by temperature, water activity and chemical composition of the parent material. Lateritic bauxites, ferricretes and latosols are witnesses of the succession of paleoclimates throughout the last 150 million years, since the Atlantic opening.

Keywords: laterites, ferricretes, latosols, conakrytes, bauxites, hematite, goethite, kaolinite, gibbsite, boehmite

Introduction

Bauxites (massive or pisolitic, and often indurated), conakrytes (massive or reticulated and often indurated), latosols (soft and microglaebular) and ferricretes (nodular and always indurated) are lateritic covers, widely distributed in North and South America, in West, Central and East Africa, as well as in Australia, India and South East Asia. These laterites form under tropical climates depending on rainfall, temperature, length of the dry season and on the nature of the parent material. Their geographic distribution is larger than the latitudinal zones of climates under which they normally form or develop. Almost all of them are very old: some are fossil, others are still active, but most of them are polygenic.

Some bauxites formed under humid conditions and later evolving under a drier climate, may generate ferricretes localised at the bottom of profiles, while ferricretes formed under seasonally contrasted climate, later evolving under wetter conditions may generate a new bauxitic horizon within a soft kaolinic latosol (Tardy *et al.*, 1991; Tardy and Roquin, 1992; Tardy, 1993).

CLASSIFICATION OF IRON-RICH LATERITES

Tardy (1993) distinguishes two mechanisms of iron accumulation: concretion and excretion as well as four kinds of iron-rich lateritic formations: (i) mottled horizon and nodular ferricretes, (ii) microglaebular latosol, (iii) conakrytes of massive structures and (iv) plinthites and petroplinthites.

Ferricretes: nodular iron-rich accumulations

Ferricretes or 'cuirasses ferrugineuses' *stricto sensu* are indurated iron concentrations, showing generally a noticeable nodulation. The words ferricrete, calcrete and silcrete are formed like concretion with 'the formant crete' which etymologically comes from Latin *con-crescere* signifying to cement or to grow together. Although these features may exhibit a concentric structure (Pettijohn, 1957) the definition of concretions does not include that they are concentric as proposed by Brewer (1964) but are only indurated or cemented accumulations. Concretion also designates the mechanism of cementation and induration, by centripetal accumulation of material, in pores of small size (Tardy, 1993). In ferricretes, the mechanism of concretion leads to the formation of indurated nodules by accumulation of hematite in the very fine porosity developed by kaolinite crystal assemblages.

In a sequence of ferricrete development from mottles (diffuse accumulations) to subnodules (nodules with diffuse edges), nodules (with distinct edges), and to metanodules (anastomosed), iron content increases, quartz content decreases drastically, while kaolinite content decreases slowly or even increases moderately. In mottles goethite dominates hematite, but in well developed nodules the contrary is observed. The ratio hematite/(hematite + goethite) increases from the mottled zone to the ferricrete zone.

Concretion and nodulation, the fundamental process of ferricrete formation, is based on the association of hematite and finely crystallised kaolinite.

Compared to hematite (Fe_2O_3), goethite is hydrated ($Fe_2O_3.H_2O$). Gibbsite ($Al_2O_3.3H_2O$) is more hydrated than kaolinite ($SiO_2.Al_2O_3.2H_2O$). The stability of hematite–kaolinite nodules is ensured as long as hematite and kaolinite are stable, i.e. they are not rehydrated or desilicated.

Tardy (1993) has shown that this association of dehydrated or poorly hydrated minerals is very stable and develops under tropical climates with a long dry season. This paragenesis hematite–kaolinite, when previously formed under contrasted tropical climates, is even stabilised in more arid conditions. In contrast, nodules of hematite and kaolinite are destabilised in humid tropical conditions, particularly under the great equatorial forest (Beauvais and Tardy, 1991).

Latosol: a microglaebular iron-rich laterite

Beauvais (1991) and Beauvais and Tardy (1991) have shown that, under a humid climate, the transformation of a ferricrete into a microglaebular latosol corresponds to the transformation of a part of kaolinite into gibbsite by desilication and hydration, and to the transformation of hematite into goethite by hydration. During this process, the size of nodules is reduced and they are transformed into microglaebules.

Tardy and Roquin (1992) and Tardy (1993) have delineated the climatic limits of formation of latosols and ferricrete by taking into account their distribution in both Brazil and Africa.

Finally, ferricretes form under tropical climates which are warm, humid and seasonally contrasted ($T \simeq 25°C$; $1100 < P < 1700$ mm y^{-1}).

An increase in humidity to above 1700 mm y^{-1} or a decrease of temperature to below 25°C act in favour of the dismantling of ferricretes and their transformation into latosols (Tardy and Roquin, 1992).

Conakrytes: massive and non-nodular iron accumulations

There are non aluminous iron accumulations which develop from non aluminous parent rocks, such as dunites, similar to those described by Bonifas (1959), in Conakry (Guinea). They are widely distributed lateritic products formed by weathering of ultramafic rocks and are characterised by massive or crystalliplasmic structures and the absence of concretions or nodules. Consequently they cannot be called ferricretes even if indurated. They were called *conakrytes* (Tardy, 1993)

Orthobauxitic profiles (discussed later) are very often capped by ferruginous hardcaps (Grubb, 1971) which were improperly named laterites by Balasubramanian *et al.* (1987). As in Mali (Tardy, 1993), these ferruginous horizons are often gibbsitic and of massive structure and, consequently, do not exhibit concretions. The absence of concretion is due to the fact that under very humid climates gibbsite forms instead of kaolinite. Hardcaps are not ferricretes in the sense of Nahon (1976) but aluminous conakrytes associated with ferruginous bauxites.

Plinthite: a cutanic and reticular iron-rich laterite?

Camargo *et al.* (1988), in the Brazilian soil classification, referring to the FAO soil classification (FAO-UNESCO, 1975), and numerous other researchers describe a plinthite as an iron accumulation showing laminar, reticular or polygonal organisation. An iron accumulation principally characterised by mottles or nodules, which result from concretion, must be classified as a mottled horizon (soft material) or a ferricrete (hardened material).

Consequently, if the reading of the term reticular is correct, an iron accumulation characterised by iron-rich reticular cutans more abundant than nodules may be classified as a plinthite (soft material) or petroplinthite (hardened material). The first should correspond to a gley, the second should correspond to a pseudo-gley.

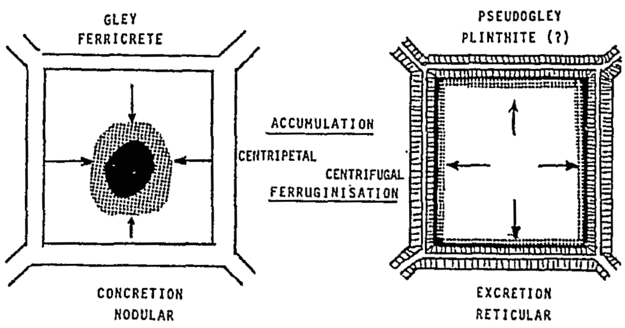

Fig. 1 Concretion (mottle and nodule formation) versus excretion (cutan formation): two processes of iron accumulation which may allow, if acceptable, the distinction of ferricretes from plinthites. (from Tardy, 1993).

Tardy (1993) has shown that what he called *excretion* and *incrustation,* which appear as cutanic accumulations, have to be clearly distinguished and separated from *concretions.* A cutan of excretion results from a centrifugal transfer of the argillaceous matrix with a porosity of small size towards the voids and the porosity of large size. A cutan of incrustation results in a transfer of matter which goes from voids and the porosity of large size towards the soil matrix. *Excretion* and *concretion* are opposite with respect to features (cutan versus nodule) and to processes (centrifugal versus centripetal). *Excretion* and *incrustation* are similar with respect to features (cutans in both cases) but are of opposite polarity (centrifugal versus centripetal). *Incrustation* and *concretion* are opposite with respect to feature (cutan versus nodule) but similar with respect to the polarity of processes (centripetal towards the porosity of fine size). The process of excretion corresponds to the leaching of iron from kaolinitic domains and to the cutanic accumulation of hematite in the voids. Excretion is clearly distinguished from concretion which corresponds to a leaching in domains close to the voids and an accumulation of hematite in domains rich in kaolinite.

Obviously this distinction was not taken into consideration so that plinthite and ferricrete are both indistinctly used to designate all kinds of iron accumulations. It is suggested here that plinthites and petroplinthites, defined as iron cutanic and reticular accumulations resulting from a process of excretion, have to be clearly separated from mottled horizons and ferricretes which are iron accumulations resulting from a process of concretion (Fig. 1). Climates of development are distinct. Mechanisms of formation are different.

CLASSIFICATION OF LATERITIC BAUXITES

The bauxitisation of very thick lateritic profiles is slow, requiring millions to tens of millions of years to form. This is the reason why bauxitic profiles have been evolving under different types of climatic and morphological situations which do not necessarily correspond to their conditions of formation.

Protobauxites

Protobauxite is the name of a gibbsitic soil that could be considered as the precursor of a lateritic bauxite. It is rather difficult to determine with precision the time required for transformation and what is the type of soil which could be the precursor of thick bauxitic profiles. Tardy (1993) admitted that among the different types of oxisols (sols ferrallitiques, in the French classification) the most sensitive to bauxitisation are the red or the yellow oxisols in which gibbsite, goethite and hematite dominate and where kaolinite and quartz are, at least originally, subsidiary (Sieffermann, 1973).

Orthobauxites

The prefix *ortho* in Greek means normal. Orthobauxites are products of evolution of gibbsitic protobauxites, developed under an annual rainfall greater than 1700 mm y^{-1} (Tardy, 1993).

A typical orthobauxitic profile is made of three major horizons (Valeton, 1972, 1981; Aleva, 1979, 1981, 1982, 1989; Bardossy, 1989; Bardossy and Aleva, 1990). From the top to the bottom one finds:

- a ferruginous, hematitic and gibbsitic horizon, red in colour, located close to the surface;
- a bauxitic horizon, less coloured, less ferruginous and more aluminous, with gibbsite and hematite;
- an argillaceous horizon, rich in kaolinite, poorly ferruginous and red-yellow in colour.

Typical orthobauxitic profiles are those of Mounts Bakhuis, Surinam (Aleva, 1981), Jarrahdale in the Darling Range, Australia (Grubb, 1971), Mount Tato at Lakota in the Ivory Coast, Africa (Boulangé, 1983, 1984) and some profiles of Famansa in Mali, Africa (Tardy, 1993), which are of Cretaceous age (Michel, 1973).

There are two types of bauxites in Famansa: orthobauxites and metabauxites. The orthobauxites are homogeneously red, and do not exhibit nodules, concretions or pisolites. Over thicknesses of about 10 m they are constituted of gibbsite, hematite and goethite. From the bottom to the top of profiles, typical orthobauxites show an increase in iron (goethite and hematite) versus aluminium (gibbsite) content, an increase in the hematite/goethite ratio and a decrease in the content of quartz and kaolinite (Tardy, 1993).

An orthobauxite is dominantly gibbsitic in the thick intermediate horizon and does not show boehmite, pisolites or concretions. It is normally capped by a conakryte when developed from a ferruginous parent rock.

There are several orthobauxitic profiles which do not exhibit a kaolinitic layer at the base and where bauxite develops down to the contact with the unaltered parent rock. The volume and the architecture of the parent rock are preserved and that is the reason why Boulangé *et al.* (1973, 1975) and Boulangé (1984) call these formations isalteritic bauxites.

Cryptobauxites

In Amazonia, bauxites are widespread. Lucas *et al.* (1986) and Lucas (1989) have presented an interesting synthesis concerning the ore deposits of Juriti and Trombetas. The parent rocks are sandstones and argillites of Alter-do-Chão from the later Cretaceous or the early Tertiary (Daemon, 1975). All bauxitic profiles are capped by an argillaceous horizon, very rich in kaolinite and poor in quartz, called Clays of Belterra and considered by Sombroek (1966) and Tricart (1978) as a Quaternary sedimentary lacustrine formation; by Grubb (1979), Kotschoubey and Truckenbrodt (1981) as a Pliocene lacustrine or desertic deposit; and finally by Aleva (1981, 1989) as a sedimentary cover. Chauvel *et al.* (1982) and Lucas *et al.* (1984) first called attention to a pedogenetic origin, while Tardy (1993) proposed that the pedogenetic phase takes place in a biogenic formation. The peculiarity of this type of bauxite comes from the fact that a gibbsitic horizon is interbedded between two kaolinite-rich horizons.

It is also interesting to remark that hematite is associated with gibbsite in the bauxitic horizon while goethite is the iron mineral dominant in the superficial layer. We agree with Lucas (1989) that bauxites of Amazonia are polygenic. They are similar to gibbsitic soils of Cameroon such as those described by Muller (1987). Both were considered by Tardy (1993) to be ancient ferricretes, formed under seasonally contrasted tropical climates and later dismantled under a more humid tropical climate. Gibbsite forms in place of the ancient ferricrete, and continues to develop in situ, close to the water table (Lucas, 1989) but below a thick kaolinic soft horizon, so that the bauxite layer is called cryptobauxite. This peculiar distribution implies a strong necessity of supplying silica from the lower to the upper part of the profile. Several biological processes can be responsible for that: termites (Truckenbrodt *et al.*, 1991) or phytolites (Lucas *et al.*, 1993). Cryptobauxites are common in equatorial forests and, if really polygenic, characterise a paleoclimatic succession which has been moving from arid to humid. The opposite is observed for the metabauxite evolution.

Metabauxites

Metabauxites are orthobauxites, initially formed under a tropical humid climate and later transformed under warmer and drier climates. *Meta* in Greek means which comes later. Metabauxites are diagenetised bauxites (Tardy, 1993).

Typical metabauxite profiles

Some of the most typical profiles that we can classify as metabauxites, are those of Weipa and Pera Head, in the Cape York Peninsula, N.E. Australia. They were described by Loughnan and Bayliss (1961) and Loughnan (1969). Over a thickness of 10 m, a quartz–argillaceous sandstone is transformed into an aluminium-rich bauxite. From the bottom to the top of the profile, quartz and kaolinite, always present, diminish while gibbsite and boehmite increase. In the lower part, goethite dominates while in the higher part, hematite becomes the dominant iron mineral.

The metabauxite profile of Famansa in South Mali was described by Tardy (1993). This so-called white bauxite profile

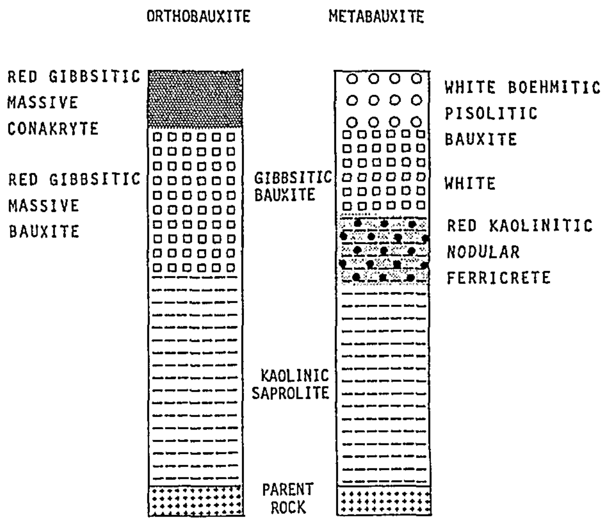

Fig. 2 Schematic distribution of boehmite, gibbsite, kaolinite and hematite in conakrytes associated with orthobauxites on one hand and in ferricretes associated with metabauxites on the other hand (from Tardy and Roquin, 1992; Tardy, 1993).

exhibits, over 10 m of thickness, an increase in aluminium, gibbsite and boehmite and a decrease in silicon towards the profile surface. The three ratios boehmite/(boehmite + gibbsite), hematite/(hematite + goethite) and gibbsite/(gibbsite + kaolinite) rise constantly from the bottom to the top of the profile. In this profile, iron does not accumulate in the superficial horizon but at depth, between 6 and 8 m, forming a typical kaolinite–hematite rich nodular ferricrete.

Metabauxites are deferruginised at the top but ferruginised at the bottom of profiles. The massive gibbsitic structure is replaced by a boehmitic, pisolitic structure. In orthobauxites, iron in hematite and aluminium in gibbsite are associated at the top of the profile forming conakrytes of massive structure. In metabauxites, at the surface of profiles, iron and aluminium in boehmitic pisolites separate, while in the ferricrete located at the bottom, iron in fine grained hematite and aluminium in kaolinite are again associated.

Regional metabauxitisation

Balkay and Bardossy (1967) first pointed out that the amounts of boehmite in bauxites of Western Africa, increase from the south to the north.

Seven regions were distinguished by Bourdeau (1991), who studied 3750 analyses of samples collected by Pechiney-Sarepa

Table 1 Elements of classification of iron and aluminium laterites

Name	Structure	Al (contents)	Fe	Hematite (size)	Goethite	Gibbsite (contents)	Boehmite	Kaolinite
Conakryte	crystalliplasmic	poor	abundant	large	present	present	absent	absent
Ferricrete	nodular	moderate	abundant	very small	present	possible	absent	abundant
Orthobauxite	massive	abundant	moderate	large	present	abundant	absent	absent
Metabauxite	pisolitic	very rich	poor	very small	absent	present	abundant	present
Latosols	microglaebular	medium	medium	small	moderate	frequent	absent	abundant

Note that hematite is always present but in different sizes and gibbsite is always present but in different proportions

Table 2 Geochemical and mineralogical classification of laterites

Name	Geochemical process	Mineral constituents	Geochemical composition
Conakryte[1]	hydro-ferrallite	goethite, hematite, gibbsite	$Fe_2O_3.H_2O.Al_2O_3$
Conakryte[2]	ferrite	hematite, goethite	$Fe_2O_3.H_2O$
Ferricrete	xero-fersiallite	hematite, kaolinite	$Fe_2O_3.SiO_2.Al_2O_3.H_2O$
Orthobauxite	hydro-alferrite	gibbsite, goethite, hematite	$H_2O.Al_2O_3.Fe_2O_3$
Metabauxite	xero-allite	boehmite, hematite	$Al_2O_3.Fe_2O_3$
Red latosol	xero-sialferrite	kaolinite, hematite, goethite	$SiO_2.Al_2O_3.H_2O.Fe_2O_3$
Yellow latosol	hydro-sialferrite	goethite, kaolinite, gibbsite	$H_2O.Al_2O_3.SiO_2.Fe_2O_3$
Podzol	sillite	quartz	SiO_2

[1] conakrytes on aluminous rocks, [2] conakrytes on ultramafic rocks

in bauxites of Guinea and Mali: (I) Fouta Djalon in Guinea, (II) Balea, North of Guinea, (III) Bamako-West in South Mali, (IV) Falea, (V) Kenieba in South-West Mali, (VI) Koulikoro, West Mali and (VII) Bafoulabe North-West Mali. In each region, the upper or superficial and the lower horizon of the profile, were distinguished.

It is clear that from the south (humid) to the north (dry and hot) i.e. from the humid Guinea to the Sahara

water content diminishes;

- iron content decreases in the superficial horizon;
- in the deep horizon, iron content increases and aluminium decreases;
- gibbsite and goethite contents diminish, while hematite and boehmite increase;
- kaolinite content increases;
- the contrast between ratios: Al_2O_3/Fe_2O_3 in the upper horizon versus Al_2O_3/Fe_2O_3 in the lower horizon increases significantly.

From the south to the north, bauxites dehydrate, more so in the upper than in the lower horizon. Accompanying the dehydration process, a migration of iron proceeds from the top (conakryte) to the bottom of the profile (ferricrete) (Tardy, 1993) (Fig. 2).

CONCLUSION

Tables 1–3 summarise the elements of classification of iron-rich and aluminium-rich lateritic formations. They are conakrytes, ferricretes, orthobauxites, metabauxites and latosols. As well as the nature of the parent rock, climatic and paleoclimatic influences are major factors controlling the nature of laterites.

Aluminous conakrytes and orthobauxites are associated in humid conditions. Ferricretes form under seasonally contrasted climates. Ferricretes and metabauxites can be associated in semi-arid or arid conditions because metabauxites are ancient orthobauxites formed under humid climates and further dehydrated and deferruginised.

Hematite is less hydrated than goethite:

$$Fe_2O_3 + H_2O \rightarrow 2FeO(OH) \quad (1)$$

Boehmite is less hydrated than gibbsite:

$$AlO(OH) + H_2O \rightarrow Al(OH)_3 \quad (2)$$

and finally, kaolinite contains more Si but is less hydrated than gibbsite:

$$Al_2Si_2O_5(OH)_4 + 5H_2O \rightarrow 2Al(OH)_3 + 2H_4SiO_4 \quad (3)$$

Reactions of hydration–dehydration and silication–desilication are the processes of laterite climatic formation and paleoclimatic evolution. Dehydration favours concretion and formation of nodules while hydration favours excretion and development of crystalliplasmic structures. In ferricretes hydration of hematite into goethite favours the dismantling of previously formed nodules. In contrast, hydration of bauxites, favours the induration of crystalliplasmas of gibbsite. Dehydration works in the

Table 3 Climatic conditions (H: humidity; T: temperature) and paleoclimatic evolution (H_1–H_2; T_1–T_2) for controlling the laterite evolution

		Parameter		Paleoclimatic	Parameters			
	Tropical climate	H	T	evolution	H_1	H_2	T_1	T_2
Conakryte(1)	humid	medium	high	constantly humid tropical	›			›
Conakryte(2)	undifferent.	—	—	undifferent.	—			—
Ferricrete	tropical contrasted	high	medium	constantly contrasted	—			—
Latosol	cool humid	high	medium	from contrasted to humid		/	\	
Orthobauxite	humid	high	medium	constantly humid	›			›
Metabauxite	arid	low	very high	from humid to arid		\	/	
Cryptobauxite	humid	high	medium	from arid to humid		/	\	

[1] from ferrialuminous rocks; [2] from ultramafic rocks.
H_1, H_2: humidity stage 1 or 2; T_1, T_2: temperature stage 1 or 2.

direction of aggradation and induration. Hydration works in the direction of degradation and dismantling (Tardy, 1993).

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KENDAL 30 YEAR ASH DISPOSAL FACILITY EXPANSION PROJECT

BASELINE INVESTIGATION
ENVIRONMENTAL IMPACT ASSESSMENT
AND
MANAGEMENT PLAN

SPECIALIST SOILS, LAND CAPABILITY & AGRICULTURAL POTENTIAL STUDIES

Compiled For

August 2016

BASELINE, EIA & EMP – FINAL REPORT6

Sustaining the Environment

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Attention:	**Ms. Tania Oosthuizen**

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Attention: Tania Oosthuizen**.**

Dear Tania,

Re: ESKOM HOLDINGS LTD
KENDAL 30 YEAR ASH DISPOSAL FACILITY - EXPANSION PROJECT
BASELINE SOIL, LAND CAPABILITY AND AGRICULTURAL POTENTIAL STUDIES, ENVIRONMENTAL IMPACT ASSESSMENT AND MANAGEMENT PLAN

Attached herewith please find the baseline alternative assessment studies and Environmental Impact Assessment undertaken for the soils, land capability and agricultural potential of the areas under consideration for the 30 Year Ash Disposal required by the Kendal Power Generation Plant (Power Station).

Yours sincerely
Earth Science Solutions (Pty) Ltd

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Declaration

This specialist report has been compiled in terms of Regulation 33.3 of the National Environmental Management Act 107/1998 (R. 385 of 2006), and forms part of the overall impact assessment for the rehabilitation and closure of infrastructure associated with the Kendal 30 Year Ash Disposal Facility Project, both as a standalone document and as supporting information to the overall impact assessment.

The specialist Pedological and Land Capability studies where managed and signed off by Ian Jones (Pr. Sci. Nat 400040/08), an Earth Scientist with 35 years of experience in this field of expertise.

I declare that both, Ian Jones, and Earth Science Solutions (Pty) Ltd, are totally independent in this process, and have no vested interest in the project.

The objectives of the study were to:

- Provide a permanent record of the present soil resources in the area that are potentially going to be affected by the proposed development – Pre development environment,
- Assess the nature of the site in relation to the overall environment and its present and proposed utilization, and determine the capability of the land in terms of agricultural potential, and
- Provide a base plan from which long-term ecological and environmental decisions can be made, impacts of development can be determined, and mitigation and rehabilitation management plans can be formulated.

The Taxonomic Soil Classification System and Chamber of Developments Land Capability Rating Systems were used as the basis for the soils, land capability and agricultural potential investigations respectively. These systems are recognized nationally.

<u>**Signed**</u>: August 2016

Ian Jones B.Sc. (Geol) Pr.Sci.Nat 400040/08
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GLOSSARY OF TERMS

Alluvium: Refers to detrital deposits resulting from the operation of modern streams and rivers.

Base status: A qualitative expression of base saturation. See base saturation percentage.

Buffer capacity: The ability of soil to resist an induced change in pH.

Calcareous: Containing calcium carbonate (calcrete).

Catena: A sequence of soils of similar age, derived from similar parent material, and occurring under similar macroclimatic conditions, but having different characteristics due to variation in relief and drainage.

Clast: An individual constituent, grain or fragment of a sediment or sedimentary rock produced by the physical disintegration of a larger rock mass.

Cohesion: The molecular force of attraction between similar substances. The capacity of sticking together. The cohesion of soil is that part of its shear strength which does not depend upon inter-particle friction. Attraction within a soil structural unit or through the whole soil in apedal soils.

Concretion: A nodule made up of concentric accretions.

Crumb: A soft, porous more or less rounded ped from one to five millimetres in diameter. See structure, soil.

Cutan: Cutans occur on the surfaces of peds or individual particles (sand grains, stones). They consist of material which is usually finer than, and that has an organisation different to the material that makes up the surface on which they occur. They originate through deposition, diffusion or stress. Synonymous with clayskin, clay film, argillan.

Desert Plain: The undulating topography outside of the major river valleys that is impacted by low rainfall (<25cm) and strong winds.

Denitrification: The biochemical reduction of nitrate or nitrite to gaseous nitrogen, either as molecular nitrogen or as an oxide of nitrogen.

Erosion: The group of processes whereby soil or rock material is loosened or dissolved and removed from any part of the earth's surface.

Fertiliser: An organic or inorganic material, natural or synthetic, which can supply one or more of the nutrient elements essential for the growth and reproduction of plants.

Fine sand: (1) A soil separate consisting of particles 0.25-0,1mm in diameter.
(2) A soil texture class (see texture) with fine sand plus very fine sand (i.e. 0.25-0,05mm in diameter) more than 30% of the sand fraction.

Fine textured soils: Soils with a texture of sandy clay, silty clay or clay.

Hardpan: massive material enriched with and strongly cemented by sesquioxides, chiefly iron oxides (known as ferricrete, diagnostic hard plinthite, ironpan, ngubane, ouklip, laterite hardpan), silica (silcrete, dorbank) or lime (diagnostic hardpan carbonate-horizon, calcrete). Ortstein hardpans are cemented by iron oxides and organic matter.

Land capability: The ability of land to meet the needs of one or more uses under defined conditions of management.

Land type: (1) A class of land with specified characteristics. (2) In South Africa it has been used as a map unit denoting land, mapable at 1:250,000 scale, over which there is a marked uniformity of climate, terrain form and soil pattern.

Land use: The use to which land is put.

Mottling: A mottled or variegated pattern of colours is common in many soil horizons. It may be the result of various processes *inter alia* hydromorphy, illuviation, biological activity, and rock weathering in freely drained conditions (i.e. saprolite). It is described by noting (i) the colour of the matrix and colour or colours of the principal mottles, and (ii) the pattern of the mottling.

The latter is given in terms of abundance (few, common 2 to 20% of the exposed surface, or many), size (fine, medium 5 to 15mm in diameter along the greatest dimension, or coarse), contrast (faint, distinct or prominent), form (circular, elongated-vesicular, or streaky) and the nature of the boundaries of the mottles (sharp, clear or diffuse); of these, abundance, size and contrast are the most important.

Nodule: Bodies of various shapes, sizes and colour that have been hardened to a greater or lesser extent by chemical compounds such as lime, sesquioxides, animal excreta and silica. These may be described in terms of kind (durinodes, gypsum, insect casts, ortstein, iron, manganese, lime, lime-silica, plinthite, salts), abundance (few, less than 20% by volume percentage; common, 20 – 50%; many, more than 50%), hardness (soft, hard meaning barely crushable between thumb and forefinger, indurated) and size (threadlike, fine, medium 2 – 5mm in diameter, coarse).

Overburden: A material which overlies another material difference in a specified respect, but mainly referred to in this document as materials overlying weathered rock.

Ped: Individual natural soil aggregate (e.g. block, prism) as contrasted with a clod produced by artificial disturbance.

Pedocutanic, Diagnostic B-horizon: The concept embraces B-horizons that have become enriched in clay, presumably by illuviation (an important pedogenic process which involves downward movement of fine materials by, and deposition from, water to give rise to cutanic character) and that have developed moderate or strong blocky structure. In the case of a red pedocutanic B-horizon, the transition to the overlying A-horizon is clear or abrupt.

Pedology: The branch of soil science that treats soils as natural phenomena, including their morphological, physical, chemical, mineralogical and biological properties, their genesis, their classification and their geographical distribution.

Slickensides: In soils, these are polished or grooved surfaces within the soil resulting from part of the soil mass sliding against adjacent material along a plane which defines the extent of the slickensides. They occur in clayey materials with a high smectite content.

Sodic soil: Soil with a low soluble salt content and a high exchangeable sodium percentage (usually EST > 15).

Swelling clay: Clay minerals such as the smectites that exhibit interlayer swelling when wetted, or clayey soils which, on account of the presence of swelling clay minerals, swell when wetted and shrink with cracking when dried. The latter are also known as heaving soils.

Texture, soil: The relative proportions of the various size separates in the soil as described by the classes of soil texture shown in the soil texture chart (see diagram on next page).
The pure sand, sand, loamy sand, sandy loam and sandy clay loam classes are further subdivided (see diagram) according to the relative percentages of the coarse, medium and fine sand subseparates.

Vertic, diagnostic A-horizon: A-horizons that have both, high clay content and a predominance of smectitic clay minerals possess the capacity to shrink and swell markedly in response to moisture changes. Such expansive materials have a characteristic appearance: structure is strongly developed, ped faces are shiny, and consistence is highly plastic when moist and sticky when wet.

1. INTRODUCTION AND PHYSIOGRAPHY

1.1 Introduction

The Kendal 30 Year Ash Disposal Project (K30ADP) has considered a number of alternatives within the vicinity of the Kendal Power Utility, with a short list of sites having been tabled from seven original sites. The shortlist included the four sites of B, C, F and H.

The rationale behind the short listing is discussed and covered in a separate document entitled "Kendal 30 Year Ash Disposal Project – Scoping Report". In this document, the desktop assessment of all of the alternatives is contemplated and the rationale behind the shortlisting of the four candidate sites is described.

The sites of interest and for which the baseline has been completed are situated to the northeast, centre and east of the Kendal Power Station, one of the operating utilities situated on the eastern Highveld of the Mpumalanga Province in South Africa (Refer to Figure 1 – Locality Plan).

The sites (B, C, F and H) comprise a total area of approximately 5,500ha of primarily cultivated or mined out land. The sites are considered "brownfield sites", the impacts of commercial farming and/or mining operations rendering these areas disturbed.

In addition, the cumulative effects of the power utility have been considered when assessing the baseline for the soils (dust fallout and the effects of dirty water on the soils) and land capability.

The effects of the existing activities and developments are clearly evident in the immediate vicinity as well as on the sites being considered, with erosion, compaction and to some degree contamination having varying degrees of impact on the soil resource and the capability of the land.

Eskom Holdings Ltd is in the process of applying for a right to expand the Ashing Facilities that it requires for the on-going operation of its power utility. This has entailed the expansion to its existing facility (the Continuous Ashing Project), in addition to the 30 Year Ashing project that will see the utility to its predicted closure. The size of the facility needed has been based on a final height of between 50m and a 100m, with a resultant footprint area of between 770ha and 520ha respectively

The process involves the conveying of the "fly ash" that is produced as a by-product and waste stream from the burning of coal and carbonaceous products in the coal fired power generating plant at Kendal Power Station to the new Ash Disposal using overland conveyers.

In addition to the actual Ash Disposal, a number of support infrastructures are required to manage and operate the facility. These include a dedicated conveyer line, access roads and servicing corridor as well as a well-engineered and dedicated water seepage and stormwater control facility.

The Ash Disposal (30 Year Facility) and associated developments (Return water dams etc.) will definitely result in a number of negative impacts to both the soils and land capability of the area and its immediate surroundings and will potentially have negative effects for the associated ecology and biodiversity that is dependent on the vadose zone and shallow soil environment.

In an attempt at quantifying the potential impacts that might result, and in order to meaningfully develop a management plan that can mitigate the effects of the planned activities it is imperative that an understanding of the pre development aspects and baseline conditions for the various alternatives are understood and documented, and that the most sustainable option is considered.

The end land use will inevitably be quite different from that mapped in the baseline study, with the Ash Disposal designed as a permanent feature that will be capped and managed as a topographic high in the present landscape. The utilisation and final land use for this feature will need to be determined as part of the final closure plan (as yet unknown/undecided), while the sustainability of the final design and utilisation plan will need to ensure that the structure is stable and free-draining. This will require a well-structured and planned construction phase, with a workable storage and stockpiling plan that will maintain the soils structural and biological conditions through the storage stage and into the rehabilitation and closure operations.

During the Scoping Phase of this project, Site C Ashing Facility was considered the best candidate site in terms of the soils and land capability assessments. However, based on the field assessments undertaken for the baseline, considerations have placed Ash Disposal Site F (F1 and F2) as the preferred site. The following in depth investigation of the four candidate sites will illustrate why the choice has changed.

It was further decided by the lead consultants in collaboration with the client that Site H was the candidate site for which additional agricultural potential studies were needed and the EI assessment completed.

Disturbance of the baseline environment will potentially result in the sterilisation of the soil resource and eco system services, with salinization and contamination of the site due to the concentration of salts and the seepage of concentrated dirty water into the underlying soils and strata.

The impacts have been assessed, and a number of management and mitigation measures tabled. These management measures are important to the long term sustainability of this development, if a stand-alone and walk away solution is to be achieved at closure.

The concept of No Net Loss (NNL) will indeed be challenged, and the possibility of Offsets will need to be considered due to the inevitable loss of resource and eco system services.

Of added importance to the earth sciences (physical environment) is an understanding of the socio economics of an area and the possible impacts that the development and its activities (transportation and deposition of a by-product and waste stream) could have on the land owners and land users that make a living or sustain themselves from the soils. This includes the effects that might be felt off site due to the erosion of soil by wind and water, and the downstream effects of sedimentary load and soil deposition.

An evaluation at a desktop level of the geomorphology of the area (topography, geology, geohydrology and hydrogeology) indicated that an investigation of all of the specialist earth sciences would be necessary if a sustainable solution was to be found for the many aspects of change that could affect the area due to a project of this nature.

These (soils and land capability), are but two of the specialist studies that have been earmarked as important to the development of the sustainability plan.

The survey intensity and coverage proposed for the soils and land capability baseline studies was tailored so as to obtain sufficient scientifically derived information that a statistically reliable information set was available, and that the information could be used for the assessment of impacts and the planning of a meaningful management plan for mitigation and the minimisation of the effects.

These studies are not intended, and must not be used for engineering designs other than the soil stripping and rehabilitation planning. Detailed geotechnical evaluations for materials sourcing and use and the strength of materials are essential for any engineering purposes.

One of the more important outcomes of the soil characterisation and classification exercise was the delineation and characterisation of the dominant soil groupings, and the rating of the soil sensitivity in terms of the activities being proposed. These aspects are considered meaningful tools and systems that can be used to identify areas that will require added inputs and or consideration in terms of legal requirements and or licensing, and will help the construction and operational teams in better managing the facility through construction and into the closure phases of the project.

In addition, and as part of understanding the sustainability equation for any new development is an appreciation for the agricultural potential of the area under consideration.

The water law and agricultural authorities require that soil wetness and the agricultural potential of the soils are assessed, with the area in question being considered an important area of food security for the Southern African region in general, and South Africa in particular (local and export markets).

The baseline has highlighted the hydromorphic soils and the shallow ferricrete based materials as areas of high sensitivity and of concern in terms of both management as well as the contribution of these areas to the biodiversity and ecological importance in the area, while the agricultural potential has been measured as a separate issue in terms of the "land capability" rating (a measure of the arable, grazing or wilderness potential of the land - Chamber of Developments – Land Capability Rating)

The proposed Ash Disposal Facility will inevitably impact on some of the hydromorphic environments identified, with much of the support infrastructure (Return water Dams and Water Control Facilities) having been planned to either traverse the wet based soils and topographic low lying areas that form the streams and water ways, or directly within these features.

These issues have been dealt with in more detail as part of the impact assessment.

The sensitive sites (predominantly shallow soils, streams, water ways and river crossings) will need to be discussed in more detail with the wetland scientist and hydrologist as part of the final design planning. Only with the inputs of the related earth sciences will a full understanding and more in-depth comprehension of these issues be obtained. This information (impact assessment) is invaluable to the development of a workable and sustainable management plan that is based on the spatial extent of the areas of concern.

All of these activities and the resultant impacts and effects will ultimately have significance to the biodiversity and ecological status of the site and surrounding areas.

This report has been compiled in line with the Guideline Document for Impact Assessment philosophy and Significance Rating System (NEMA), and ratings of impact significance have been made using the Impact rating System as required by the lead Consultants (Zitholele Consulting).

The impact assessment aims to identify and quantify the environmental and/or social aspects of the proposed activities, to assess how the activities will affect the existing state, and link the aspects to variables that have been defined in terms of the baseline study.

In addition, the impact assessment aims to define a maximum acceptable level of impact for each of the activities, inclusive of any standards, limits and/or thresholds, and assesses the impact in terms of the significance rating as defined by the lead consultants (Refer to Appendix 2). This required that the cumulative effects are considered, and that the common sources of impact are detailed.

1.2 Project Description

The project is considered a Greenfields Project in terms of the Ash Disposal that is being proposed and the associated activities that will support the project, but as a Brownfields Project due to the intensive agricultural cultivation, existing mining activities and the cumulative effects of existing power generating activities and their support infrastructure in the area.

The design plans issued as part of the ToR supplied envisage the development of a stand-alone facility as close as possible to the Power Station. The facility will require a significantly large footprint (520ha to 770ha) for the actual Ash Disposal, as well as catering for the collection and management of storm water and the conveyencing of the ash to the disposal facility.

All of these activities will impact the existing environment to a greater or lesser degree, and will be rated in terms of the site sensitivity and land capability (Refer to Figure 1 - Locality Plan).

The size of the venture is considered to be medium to large in terms of the volumes of waste that are planned for deposition, as well as being moderate to large in terms of the footprint of impact that the activities will have on the surface extent. The Life of the Operation (LoO) is estimated and planned for between 30 years and 37 years.

The final height of the facilities and the engineering design of the side slopes have been configured to minimise the size of the footprint and optimise the life of the facility. These actions will help to reduce the overall impact on the underlying resources.

The facility will be serviced by a stormwater management system (Trenches, Berms and Dams) that will contain all dirty water and separate the clean water. These facilities are part of the footprint of impact and have been considered as part of the overall effect that the proposed development might have on the physical and socio economic environments.

The existing Ashing Facility, the Kendal Power Station, the coal mining and the intensive commercial farming activities within the zone of influence of the proposed development will all have an effect on the cumulative impacts. The additional impacts from the 30 Year Ash Disposal Development will probably be confined to the site and the immediate surrounds/buffer zone if well managed, but could potentially leave the site and be transported by wind or water over larger distances if not well managed.

The geology that underlie the development site and from which the in-situ soils are derived, are typical of the South African coal fields that occur on the eastern Highveld of South Africa, and comprise for the most part horizontally bedded sediments of the Vryheid Formation of the Ecca Group (lower Permian age). An understanding of the geology has aided in the soil mapping and characterisation exercise.

The Vryheid Formation consists of alternating sandstones and shale's ranging between coarse and gritty sandstones to shale's and mudstone layers and the variations between the two extremes. These moderately old formations have been intruded and disturbed by relatively much younger intrusives that comprise dolerite sills and dykes for the most part.

Eskom Holdings SOC Ltd at their Kendal Power Utility requires additional footprint area for the deposition of the ash by product, and although they have potentially secured the extension to the exiting Disposal, this will only cater for a portion of the life expectancy of the Power Station.

The deposition of waste produced by the coal fired power station is a recognised method of managing the by-product, the premise made being that the utilisable soils will be stripped and stored as a matter of design and good practice, while the land use and its inherent capability and resultant sensitivity will be considered prior to any development decisions being made.

Impacts from the erosion of the waste by water or wind are a consideration to be included in the design decisions, while the potential for the salinisation and contamination of the soils underlying the site and those in storage are risks to be considered in the impact statement.

Added impacts include the spillage of hydrocarbons and other reagents that might be needed as part of the Ash Disposal operation, the movement of dirty water onto stored or the adjacent soils and the potential for the sterilisation and/or salinisation of these materials.

The activities associated with the deposition and storage of ash will disturb the surface features and alter the soils, land use and land capability permanently, albeit that the final disposal is planned to be shaped and covered with a soil capping that is capable of sustaining a vegetative cover under natural climatic conditions.

The end land use for this investigation and reporting has been assumed at this stage to be conservation status or possibly low intensity grazing lands.

With these assumptions as part of the rehabilitation and closure plan, it is imperative that a well-designed and sustainable soil utilisation and management plan is developed and implemented as part of the overall life of the development. The specifics of this plan will be spelled out as part of the specialist environmental management plan (EMP) for the soils and land capability.

These actions should be integral and part of the overall design philosophy.

A sustainable end use plan will need to be considered and decided on as part of the design criteria supplied, and will form the basis for the impact assessment (EIA) and management planning (EMP).

Using these well established and accepted methods of waste deposition and storage, and assuming that the lining conditions cater for the development of a barrier to infiltration of contaminants to the vadose zone and the soil layer that is left as the ash disposal footprint, the impacts to the soil environment can be limited and managed.

The use of the soils recovered from the footprint as a cover to the disposal will also assist in managing the erosion of the ash. This assumes that there will be sufficient soil material at closure, and that it has a quality that can sustain a stand-alone vegetative cover with topography that is free draining.

The permanent nature of the structures being proposed will seriously challenge the concept of No Net Loss, and the overall desire to achieve a sustainable project. Thus, an understanding of the pre development conditions is imperative, both in terms of having an accurate record of what exists now, as well as understanding the impact that an ashing facility will have, and how difficult it will be to manage and mitigate the effects.

Apart from these issues being required in terms of the law, it is important that the potential loss of an important resource (soil, land use and eco system services) needs to be understood in terms of the sustainability equation.

The soil utilisation plan will include the defining of how the mitigation will reduce the intensity and probability of the impact occurring, and what is necessary to ensure that the prescriptive mitigation proposed is clear, site specific and practical.

In addition, and as part of the practical management plan, a comprehensive monitoring system has been proposed and tabled.

The Kendal Ashing Facilities are part of the strategic development required in terms of energy production in South Africa, and although this is a proposed new development, it is part of the optimisation and extension to the life of the Kendal Power Station operation.

The lead consultants (Zitholele Consulting) contracted Earth Science Solutions (Pty) Ltd (ESS) to assist with the specialist soils and land capability sections of the baseline studies, the assessment of impacts and the development of a soil utilisation and management plan that will aid in the minimisation and mitigation for the life of the development and into the post closure (construction, operation and closure) phase.

Figure 1a shows the general location and extent of the alternatives that were considered as part of this planning, while Figures 1b, 1c 1d, 1e and 1f show the location of each of the candidate sites that were shortlisted as possible sites for the ashing facility.

Site H, chosen as the candidate site based on the weighting of all considerations has been assessed in terms of its site sensitivity, agricultural potential and land capability when considering the impact significance. These aspects were in tern used in the consideration and design of the management plan.

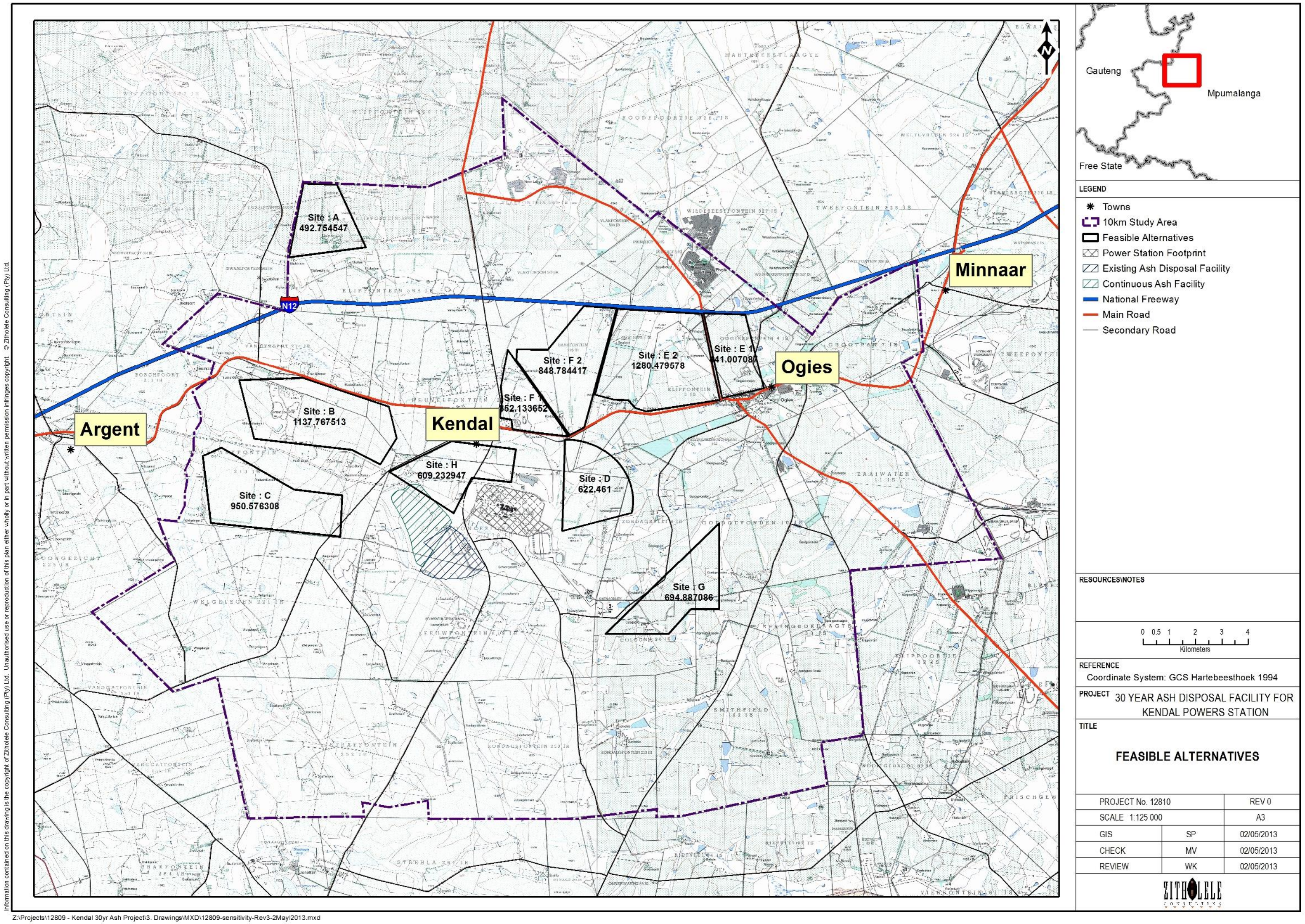

Figure 1a – Regional Locality Plan of Site Alternatives

Figure 1b – Proposed Ash Disposal Facility – Site B

Figure 1c – Proposed Ash Disposal Facility - Site C

Figure 1d – Proposed Ash Disposal Facility – Site F1

Figure 1e – Proposed Ash Disposal Facility – Site F2

Figure 1f – Proposed Ash Disposal Facility – Site H

In line with the discussions had at the alternatives workshop, and with the results of the soil and land capability studies at hand, it was incumbent on the specialist consultants to deliver a reasoned argument for the best candidate site for the 30 Year Ashing Facility. In doing this, the earth sciences used the concept of environmental "sensitivity" or site vulnerability to assist with the rating of the various sites, the soils mapping having been simplified based on the dominant soil forms, their functionality and their associated land capability.

In this way, the sustainability of the project can be measured in terms of the impacts and related mitigation, with sensitive areas being left out completely, or managed in a sound scientifically derived manner.

The baseline findings were then used to assess and rank the impacts that can be expected on the candidate site, with the management plan for mitigation being based on the activities tabled as part of the development plan and the findings of the impact assessment.

A comprehensive soil utilization plan has also been tabled as part of the EMP and has given a functional description of how the soils should be managed if the impacts are to be minimised.

The principle or concept of "No Net Loss" (NNL) has been tabled as the ultimate aim in developing a project that is sustainable. However, the deposition of a waste product such as ash and some of the activities that are being proposed for this project will definitely challenge this concept.

The activities being proposed will definitely have a negative, but variable impact on the natural resources and they are considered to be permanent. The land use will definitely change, and the capability of the soils and the land will be altered.

1.3 Methodology and Approach

The soil and land capability specialist studies have been tailored to the site specifics of geomorphology and land use, and developed as the basis for the characterisation and classification of the soils and the rating of the land capability and determination of the agricultural potential for the candidate site.

The soil mapping is based on a specific set of principles as set down in the "Taxonomic Soil Classification, a system designed for South Africa" (described in detail later), but of relevance to many of the Southern African regions as well. These norms are consistent with the NEMA Regulations, World Bank Standards and national nomenclature.

The resultant physical and chemical characteristics of the materials are used to characterise and highlight the site specific sensitivities which are then combined into dominant soils "groupings". The groupings have similar physical and chemical characteristics that will react in a similar manner to the possible impacts predicted, and for which the same mitigation and management measures can be applied under a given set of circumstances.

This simplification of the soil forms can be used by the developer more easily and with better results as part of the planning and decision making tools (Not for design purposes). In addition, the interested and/or affected parties (Public and Authorities) can make more informed and better comment based on well-developed and scientifically based information, all of which will aid in the design of the most sustainable project.

In better understanding and informing these studies on how sensitive or vulnerable a soil is, it was essential that the system being used is able to establish and measure in a repeatable manner, the aspects and determinants that contribute to a material being robust or sensitive.

The Soil Classification System and Land Capability Rating Systems supply the scientific basis and knowledge needed to determine the sensitivity or vulnerability to the soils of the different actions and activities being proposed.

The soils physical and chemical properties and the way in which these react to the elements (wind, water erosion, heat, chemical reaction etc.), the effects of having the vegetative cover removed, or their reaction to having the topsoil disturbed, and the effects of chemical impacts (ease of being taken into solution), are all aspects that have been considered and assessed in measuring sensitivity and ultimately vulnerability to development.

These measures are important when considering the impact assessment, and will ultimately dictate the mitigation and management measures (degree of input etc.) that will be required in the management of the development.

Using this philosophy the study area was investigated on a comprehensive reconnaissance grid base, with an assessment and understanding of the pre development conditions for the soils, the land capability and agricultural potential being considered as the minimum requirements for the baseline inputs to the candidate site.

The level of study and intensity (spatial variance) of observations was guided by a number of practical variables. These included the geomorphology of the site (topography, ground roughness, attitude and climate) and knowledge of the proposed development (development plan) and the actions that are planned.

No detailed soils information was available from any of the regional assessments, and although the Land Type Maps (Government) and Geological Maps were of help in understanding the proposed planning for the area and the high level understanding of the agricultural potential, land capability and associated earth sciences variables, the sensitivities and site specific variations and aspects that are important to the ecological balance of the area were lacking.

1.4 Legal Considerations

As part of understanding the consequences of the proposed development an knowledge of the national legislation that pertains to soils and related sciences is important, and is a guide in understanding the permissible standards and limits that can be considered, albeit that there are no prescribed quantitative limits that can be quoted.

The most recent South African Environmental Legislation that needs to be considered for any new development with reference to management of soil includes:

- The Conservation of Agricultural Resources (Act 43 of 1983) states that the degradation of the agricultural potential of soil is illegal.
- The Bill of Rights (chapter 2) states that environmental rights exist primarily to ensure good health and wellbeing, and secondarily to protect the environment through reasonable legislation, ensuring the prevention of the degradation of resources.

- The Environmental right is furthered in the National Environmental Management Act (No. 107 of 1998), which prescribes three principles, namely the precautionary principle, the "polluter pays" principle and the preventive principle.
- It is stated in the above-mentioned Act that the individual/group responsible for the degradation/pollution of natural resources is required to rehabilitate the polluted source.
- Soils and land capability are protected under the National Environmental Management Act 107 of 1998, the Development Act 28 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 remedied.
- The Development Act 28 of 2002 requires an EMPR, in which the soils and land capability be described.
- The Conservation of Agriculture Resources Act 43 of 1983 requires the protection of land against soil erosion and the prevention of water logging and salinization of soils by means of suitable soil conservation works to be constructed and maintained. The utilisation of marshes, water sponges and water courses are also addressed.

In addition to the South African legal compliance this proposed development has also been assessed in terms of the International Performance Standards as detailed by the International Finance Corporation (IFC).

The IFC has developed a series of Performance Standards to assist developers and potential clients in assessing the environmental and social risks associated with a project and assisting the client in identifying and defining roles and responsibilities regarding the management of risk.

Performance Standard 1 establishes the importance of:

- Integrated assessment to identify the social and environmental impacts, risks, and opportunities of projects;
- Effective community engagement through disclosure of project-related information and consultation with local communities on matters that directly affect them; and
- The client's management of social and environmental performance throughout the life of the project.

Performance Standards 2 through 8 establish requirements to avoid, reduce, mitigate or compensate for impacts on people and the environment, and to improve conditions where appropriate. While all relevant social and environmental risks and potential impacts should be considered as part of the assessment, Performance Standards 2 through 8 describe potential social and environmental impacts that require particular attention in emerging markets. Where social or environmental impacts are anticipated, the client is required to manage them through its Social and Environmental Management System consistent with Performance Standard 1.

Of importance to this report are:

- The requirements to collect adequate baseline data;
- The requirements of an impact/risk assessment;
- The requirements of a management program;
- The requirements of a monitoring program; and most importantly;
- To apply relevant standards (either host country or other).

With regard to the application of relevant standards (either host country or other) there are no specific quantitative guidelines relating to soils and land use/capability, either locally or within the World Bank's or IFC's suite of Environmental Health and Safety Guidelines. However, the World Bank's Development and Milling, guideline does state that project sponsors are required to prepare and implement an erosion and sediment control plan.

The plan should include measures appropriate to the situation to intercept, divert, or otherwise reduce the storm water runoff from exposed soil surfaces, tailings dams, and waste rock dumps.

Project sponsors are encouraged to integrate vegetative and non-vegetative soil stabilization measures in the erosion control plan.

Sediment control structures (e.g., detention/retention basins) should be installed to treat surface runoff prior to discharge to surface water bodies. All erosion control and sediment containment facilities must receive proper maintenance during their design life.

This will be included in the appropriate management plans when they are developed at a later stage in the project's life cycle.

1.5 Assumptions, Limitations and Uncertainties

It has been assumed that the total area of possible disturbance was included in the area of study, that the development plan as tabled has documented and catered for all actions and activities that could potentially have an impact on the soils and land capability, and that the recommendations made and impact ratings tabled will be re-assessed if the development plan changes.

Limitations to the accuracy of the pedological mapping (as recognised within the pedological industry) are accepted at between 50% (reconnaissance mapping) and 80% (detailed mapping), while the degree of certainty for the soils physical and chemical (analytical data) results has been based on **"composite"** samples taken from the dominant soil types mapped in the study area.

The area in question has been mapped on a comprehensive reconnaissance base, the degree and intensity of mapping and geochemical sampling being considered and measured based on the complexity of the soils noted in field during the field mapping, and the interplay of geomorphological aspects (ground roughness, slope, aspect and geology etc.).

2. DESCRIPTION OF THE PRE-CONSTRUCTION ENVIRONMENT

2.1 Data Collection and Gap Analysis

2.1.1 Review of Available Information

The specialist pedological and land capability studies have been undertaken using a phased approach, with the desktop and scoping assessment having been completed during the middle of 2013 (28th – 30th April 2013), and the baseline investigation and alternatives assessment of the shortlisted sites being completed during September 2013 (16th to 20th September 2013) and February 2014 (15th to 18th February 2014).

The sites covered in the baseline assessment were based on the development plan made available through the lead consultants (Refer to Figure 1a to Figure 1f).

The site specific nature of the proposed development (Ash Disposal), and the spatial distribution of the support infrastructure renders the impact as local to site specific, and no alternatives can/could be considered other than the no-go option.

Site sensitivities and possible “No Go” considerations have been highlighted wherever pertinent, with specific regard being given to areas of wetness, shallow soil depths, soil erosion and compaction, with contamination a consideration due to disturbance and the effects of the development. These are the most likely aspects that will affect the loss of resource.

The site specific sensitivities have been highlighted and used in the delineation of environmentally sensitive “No Go” or “High Sensitivity” areas, and have had an impact on the alternatives assessment rating of the sites considered.

These considerations are recognised as essential in the process of sustainable development and the obtaining of scientific information that is helpful in answering the IAP’s and authorities concerns.

The construction and operation of an Ash Disposal Facility will require that new infrastructure is build and operated. This will inevitably effect the natural environment. The activities will include but are not confined to, the building and operation of a dedicated conveyer line, the excavation of stormwater trenches and the building of cut-off berms and dams, and the construction of a large lined footprint (550ha to 770ha). These activities will impact the soils and change the land capability.

Based on these planned activities, it was important that the baseline study was comprehensive enough, that it could be used by the developer for site selection actions and the development of a feasible plan

The government survey maps (geological and topocadastral) and the regional descriptions were used in obtaining an understanding of the general lithological setting for the area, while discussions with the farming community helped in understanding the possible pedogenic processes that could be unique to the specific environment. However, the scale of this information is insufficient for the level of data needed for a project of this magnitude.

Field Work

A reconnaissance pedological study of the site was performed using a comprehensive grid base, for the entire footprint area and a 300m buffer zone around the areas that are being planned for the Kendal 30 Year Ashing Facility.

The Ash Disposal footprint and all associated support infrastructure and related activities will be subjected to the removal of all utilisable soil, while the footprint associated with the deeper excavations (dams etc.) will require that all of the soil and some of the soft overburden will need to be stripped and stockpiled/stored. These actions will result in the alteration/modification of the surface topography and will permanently change the land capability and land use, while the changes in the landscape (lowering or possible rising of the land surface – bulking factor) will affect the hydrological flow patterns on surface and will potentially result in areas of “ponding” and/or erosion if they are not well managed.

Ponding of surface water and the un-managed increased in infiltration of surface water into the vadose zone will have significant negative implications for the utilisation potential and land capability. These are high negative impacts that are difficult to reverse.

Field Methodology

In addition to the grid point observations, a number of samples previously taken from the Klipspruit and Bankfontein sites were used to better understand the chemical and physical attributes of the soils in the general area. The soil mapping was undertaken using the aerial photographs supplied, and the Google Earth satellite imagery (Refer to Figure 2.1.2b, 2.1.2c, 2.1.2d and 2.1.2e– Dominant Soils) orthophotographic base. Site specific samples of the soil were taken from the candidate site.

The majority of observations used to classify the soils were made using a hand operated bucket auger and Dutch (clay) auger.

Standard mapping procedures and field equipment were used throughout the survey.

The fieldwork comprised a number of days on site during which profiles of the soil were excavated and observations made of the differing soil extremes. Relevant information relating to the climate, geology, wetlands and terrain morphology were also considered at this stage, and used in the classification of the soils of the area, while the variation in the natural vegetation was also used to help in the more accurate placing of the changes in soil form.

Terrain information, topography and any other infield data of significance was also recorded, with the objective of identifying and classifying the area in terms of:

- The soil types to be disturbed/rehabilitated;
- The soil physical and chemical properties;
- The soil depth;
- The erodibility of the soils;
- Pre-construction soil utilisation potential, and
- The soil nutrient status.

Soil Profile Identification and Description Procedure

The identification and classification of soil profiles were carried out using the *Taxonomic Soil Classification, a System for South Africa (Mac Vicar et al, 2nd edition 1991*)

The Taxonomic Soil Classification System is in essence a very simple system that employs two main categories or levels of classes, an upper level or general level containing Soil Forms, and a lower, more specific level containing Soil Families.

Each of the soil Forms in the classification is a class at the upper level, defined by a unique vertical sequence of diagnostic horizons and materials.

All soil forms are subdivided into two or more families, which have in common the properties of the Form, but are differentiated within the Form on the basis of their defined properties.

In this way, standardised soil identification and communication is allowed by use of the names and numbers given to both Form and Family.

The procedure adopted in field when classifying the soil profiles is as follows:

i. Demarcate master horizons;
ii. Identify applicable diagnostic horizons by visually noting the physical properties:

  - Depth (below surface)
  - Texture (Grain size, roundness etc.)
  - Structure (Controlling clay types)
  - Mottling (Alterations due to continued exposure to wetness)
  - Visible pores (Spacing and packing of peds)
  - Concretions (cohesion of development and/or peds)
  - Compaction (from surface)

iii. Determined from i) and ii) the appropriate Soil Form
iv. Establishing provisionally the most likely Soil Family

Table 2.1.1 Explanation - Arrangement of Master Horizons in Soil Profile

<table>
<tr><td rowspan="11">SOLUM</td><td rowspan="11">(Zone in which the soil forming processes are maximally expressed)</td><td colspan="5">Arrangement of master horizons</td><td>Comments on Layers</td></tr>
<tr><td rowspan="10">O - Organic</td><td rowspan="5">C - Regic Sands (C), Stratified Alluvium (C), Man - Made Soil Deposits (C).</td><td rowspan="2">A</td><td rowspan="2">Humic,Vertic, Melanic, Orthic</td><td rowspan="10">G</td><td>Loose leaves and organic debris, largely undecomposed</td></tr>
<tr><td>Organic debris, partially decomposed or matted</td></tr>
<tr><td rowspan="3">B</td><td rowspan="3">Red Apedel, Yellow-brown Apedel, Soft Plinthic, Hard Plinthic, Prismacutanic, Pedocutanic, Lithocutanic, Neocutanic, Neocarbonate, Podzol, Podzol with placic pan</td><td>Dark coloured due to admixture of humified organic matter with the mineral fraction</td></tr>
<tr><td>Light coloured mineral horizon</td></tr>
<tr><td>Transitional to B but more like A than B</td></tr>
<tr><td rowspan="4">C</td><td colspan="2" rowspan="4">Dorbank, Soft Carbonate horizon, Hard Carbonate Horizon, Saprolite, Unconsolidated materials without signs of wetness, Unconsolidated materials with signs of wetness, Unspecified materials with signs of wetness</td><td>Transitional to A but more like B than A</td></tr>
<tr><td>Maximum expression of B-horizon character</td></tr>
<tr><td>Transitional to C</td></tr>
<tr><td>Unconsolidated material</td></tr>
<tr><td colspan="3">R - Hard Rock</td><td>Hard rock</td></tr>
</table>

Sample Analysis

Sampling of representative soils was carried out and submitted for analysis.

Factors that were considered in the laboratory included:

- Determination of the pH
- Exchangeable bases
- C.E.C. (cation exchange capacity)
- Texture (% clay)
- Nutrient status and
- Any potential pollutants

2.1.2 Description

Soil Characterisation

The soils encountered can be broadly categorised into four major groupings, with a number of dominant and sub dominant forms that have been combined and that characterise the area of concern (Refer to Figure 2.1.2b).

The major soil forms are closely associated with the lithologies from which the soils are derived (in-situ formation) as well as the topography and general geomorphology of the site, with the effects of slope and attitude of the land forms and the pedogenetic processes involved affecting the soil formation and ultimately the soil forms mapped.

The generally flat to slightly undulating topography has resulted in the in-situ formation of many of the soils and a moderately well-developed pedogenisis for the site, albeit that the retention of soil water within the vadose zone (lack of preferred horizontal flow) due to the horizontal bedding of the sediments and fine grained nature of the siltstone and mudstone interlayers has resulted in the creation of an inhibiting layer (calcrete/ferricrete) within some of the soil profiles.

The resultant perched water within the profile creates areas of relatively much wetter soil, a factor that is considered important to the ecology and biodiversity of the area.

It is hypothesised that, the ferricrete layer that is found associated with the horizontally bedded sediments is responsible for the restrictive layer that is holding water within the soil profile and resulting in the development of moderately extensive areas of wet based soils. This feature is inherently important to the fauna and flora and general ecology of the area.

The occurrence of extensive calcrete and/or ferricrete horizons within the soil profile classify as “relic” land forms for the most part, albeit that a significant area of more recent hard plinthite or laterite development was mapped in association with the streams and secondary rivulets in the area.

The relic land forms are commonly associated with hillside seeps and “sponge zones” (Refer to Figure 2.1.2b through 2.1.2e), both of which are associated with possible wetland development.

These ferricrete layers occasionally outcrop at surface as ouklip or hardpan ferricrete and are the basis for many of the pan structures found within the sedimentary profile and landscape of this region. These features are regarded as sensitive to highly sensitive features.

In addition, and as part of these sensitive systems, are the "transition zones" that contribute (soils within the pan catchment) to the wetland catchment systems. These areas also need to be considered as part of the sites with a status of high sensitivity. The importance of these zones cannot be over emphasised, as it is these sites and soils that act as the feeder zones to the wet based soils and wetland systems.

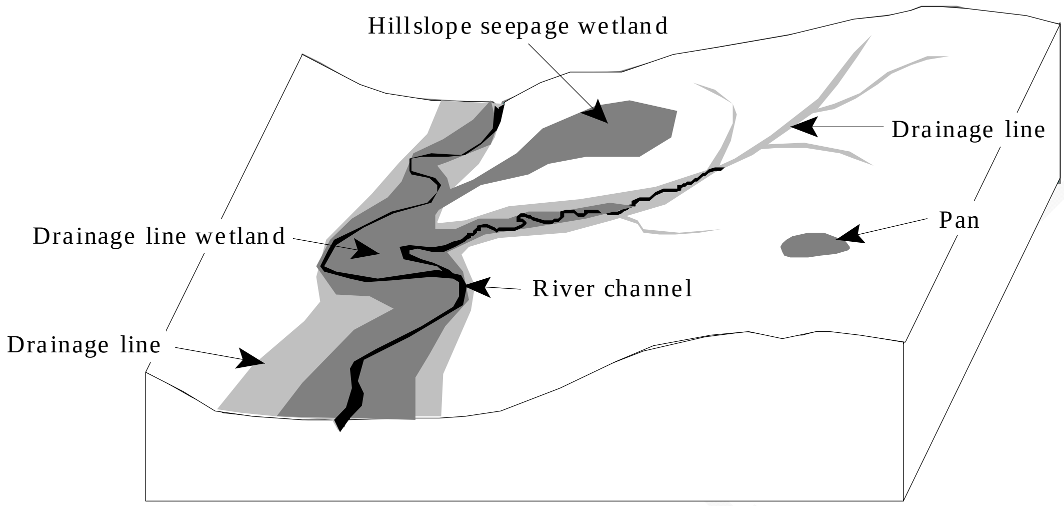

Figure 2.1.2a - Schematic of the Wet Lands and their relation to Topography.

The dominant soils classified are described in terms of their physical and chemical similarities and to some extent their topographic position and resultant pedogenisis, with their spatial distribution being of importance to the management recommendations (Refer to Figure 2.1.2b – Dominant Soils) and soil utilisation plan. The major soil groupings are described in more detail later in this section.

The soils mapped range from shallow sub-outcrop and outcrop of hard plinthite and parent materials (Sediments and intrusive dolerite) to moderately deep sandy loams and sandy clay loams, all of which are associated with either a rocky outcrop of sedimentary parent rock, or ferricrete/laterite "C" horizon at varying depths. The saprolitic horizons are generally quite thin, with soil occurring on hard bedrock in most instances mapped.

When considering the sensitivity of a wet based soil, the depth to the inhibiting layer and the amount of redox reaction present (noted in the degree of mottling and more importantly the greyness of the matrix soil) within the profile dictates the degree of wetness in terms of the "wetland delineation classification". This will have an effect on the ecological sensitivity of the site.

The shallow, to very shallow soil profiles are generally associated with an inhibiting layer at, or close to surface, and as already alluded to, is the defining feature that controls the ability (or not) of water to flow vertically down and through the profile (restrictive layer) and dictates the degree of drainage for the soil.

The degree to which the plinthite layer has been cemented (friability of the ferricrete) will determine the effectiveness of the layer as a barrier to infiltration, while the depth of overlying soil will dictate how easily or difficult it is for the soil water to be accessed by the fauna and flora, and in the extreme case weather water is held at surface as a pan.

The friability or ease of excavation (dig-ability) of the ferricrete will also have an effect on the amount of clay mineralisation that the soil contains within this horizon, and will in turn influence the water holding characteristics of the soil and the degree of structure.

In addition to the soil system of classification, a system has been developed for the describing and classification of ferricrete (Refer to Appendix 2) as well. This has been used in better understanding the land forms and the overall geomorphology of the site, and makes for a more meaningful and repeatable system of reporting the workability of the sols and underlying materials. This is important for both the construction phase, where soils need to be stripped, and the rehabilitation phase where the order of replacement is important.

In contrast, the deeper and more sandy profiles, although associated with a similar set of lithologies have distinctly differing pedogenetic processes that are associated with, better drainage characteristics, often lower clays and a deeper weathering profile. The marked difference is often the presence or lack of iron and manganese in the parent materials.

As with any natural system, the transition from one system to another is often complex with multiple facets and variations over relatively small/short distances.

In simplifying the trends mapped, the following major soil “groupings” are of importance to an understanding of the soil workability and rehabilitation potential:

- The deeper and sandier soils are considered ***High Potential*** materials and are distinguished by the better than average depth of relatively free draining soil to a greater depth (> 700mm). This group are recognisable by the subtleness of the mottling (water within the profile for less than 30% of the season), are noted at greater depths within the profile (>500mm) and the land capability is rated as moderate intensity grazing and/or arable depending on their production potential.

  These soils are generally lower in clay than the associated wet based soils and more structured colluvial derived materials, have a distinctly weaker structure and are deeper and better drained (better permeability). The ability for water to permeate through these profiles is significantly much better than for the structured and wet based soils. In addition, the more sandy texture of this soil group renders them more easily worked and they are rated as having a lower sensitivity (Deep >500mm).

- In contrast, the shallower and more structured materials are considered to be more ***sensitive*** and will require greater management if disturbed. The group of ***shallower and more sensitive soils*** (< 500mm) are associated almost exclusively with the sub outcropping of the parent materials (Karoo Sediments) (geology) at surface, and although they constitute a relatively small percentage of the overall area of study, they have a relatively large and important function in the sustainability of the overall biodiversity of the area.

- The third group of soils comprise those that are associated with the hard pan ferricrete layer and/or perched soil water. This group of soils have a set of distinctive characteristics and nature that are separated out due to their inherently much more difficult management characteristics.

  These soils are characterised by relatively much higher clay contents (sometimes of a swelling nature), poor intake rates, poor drainage, generally poor liberation of soil water and a restricted depth – often due to the inhibiting barrier within the top 700mm of the soil profile. These soils are generally associated with a ***wet base***.

  These soils will be more difficult to work in the wet state, are difficult to store and are of the more difficult soils to re-instate during rehabilitation and at closure. They are also some of the more important soils, and as such need to be identified and stripped and stockpiled separately from the dry and more sandy soils

  The groundwater levels are reported to be relatively deep (>12m) for the majority of the area of study and are reported (hydrogeologists) to have little to no influence on the soil water and water found within the vadose zone. No perched aquifers (groundwater) are reported. This would suggest that all of the hard plinthite and ferricrete noted is as a result of soil water within the vadose zone. The development of wet based soils and moist grassland environments are mapped in association with these soil forms.

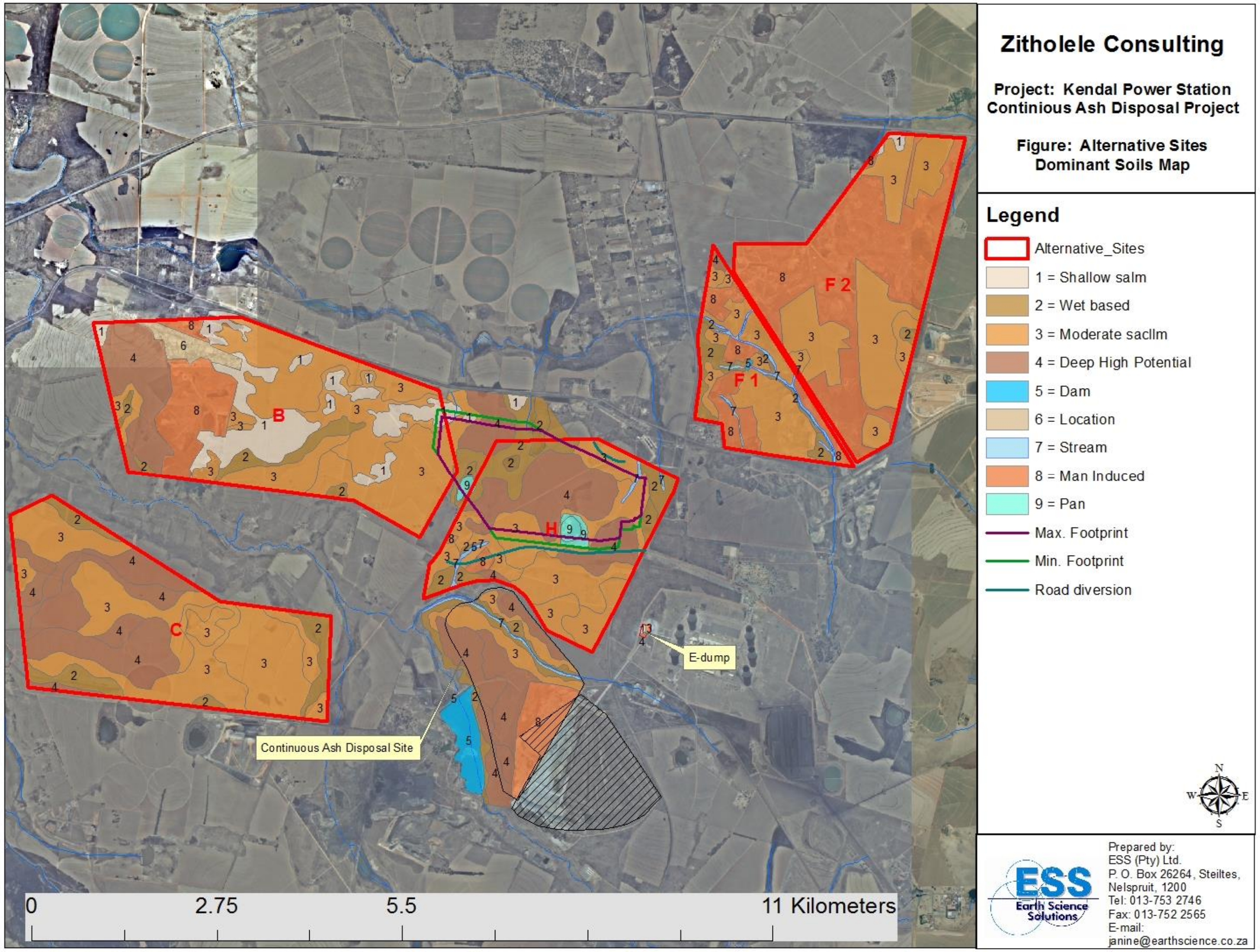

Figure 2.1.2b - Dominant Soils Map – Overall Area (All four sites)

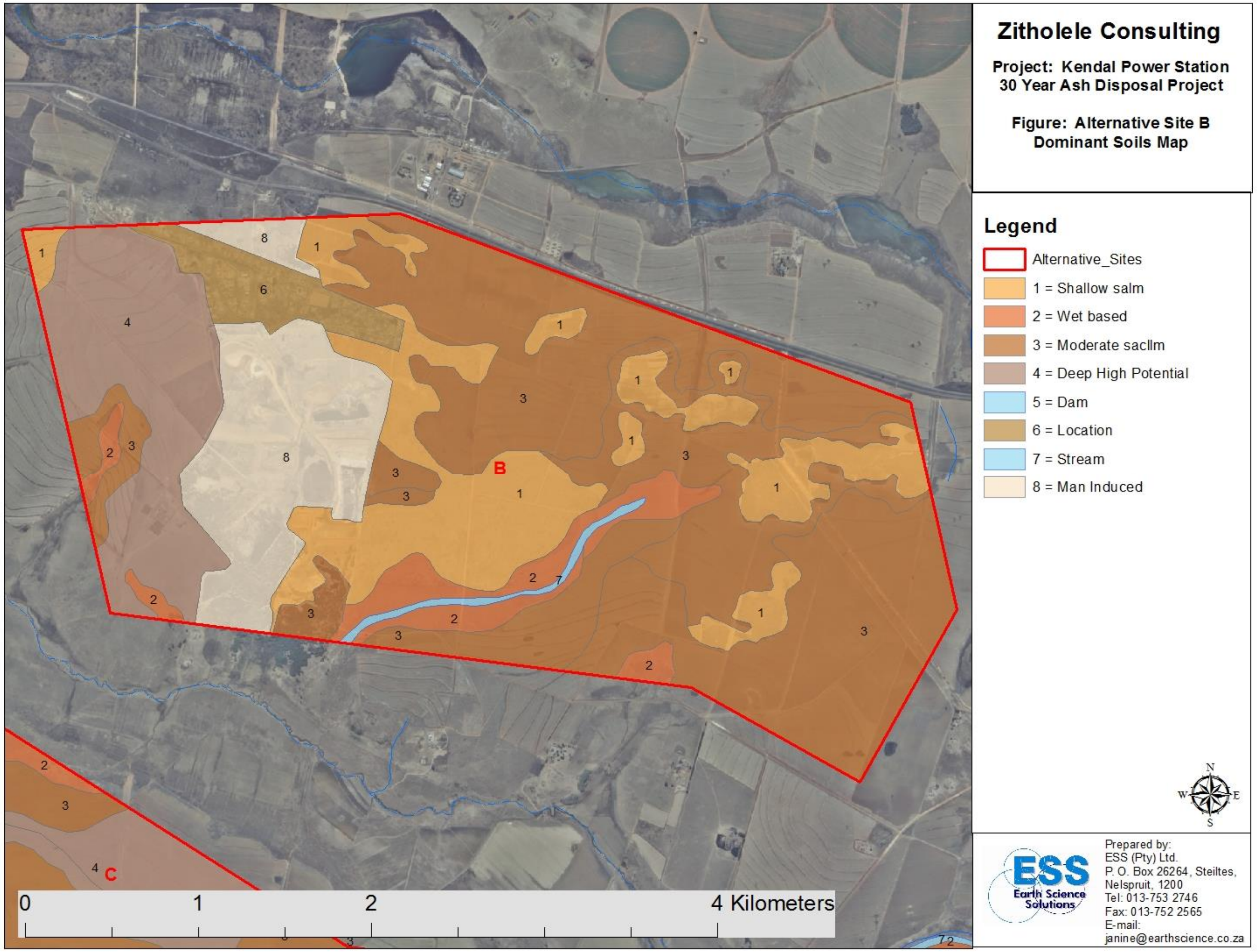

Figure 2.1.2c - Dominant Soils Map – Proposed Ash Disposal Facility Site B

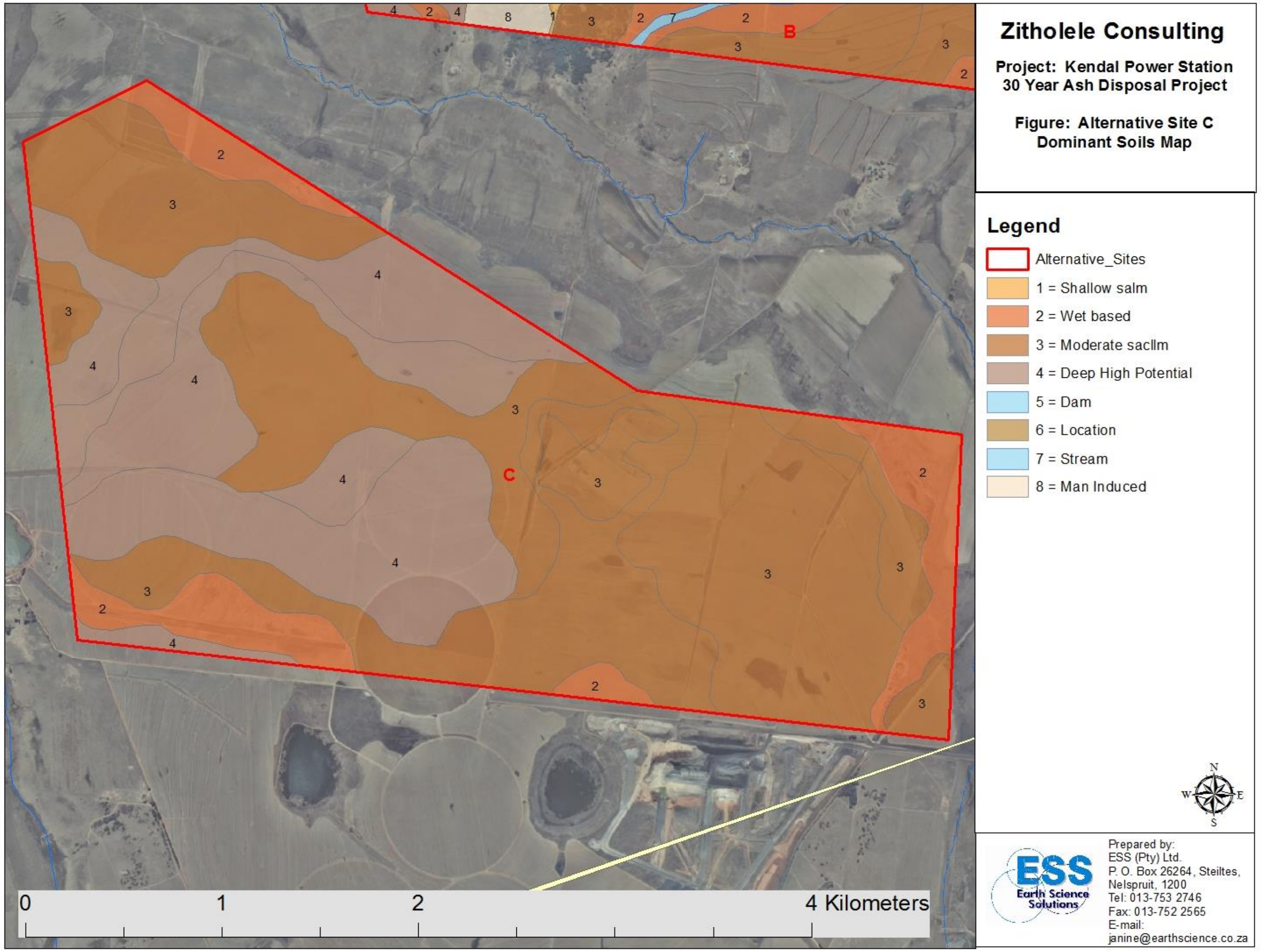

Figure 2.1.2d - Dominant Soils Map – Proposed Ash Disposal Facility Site C

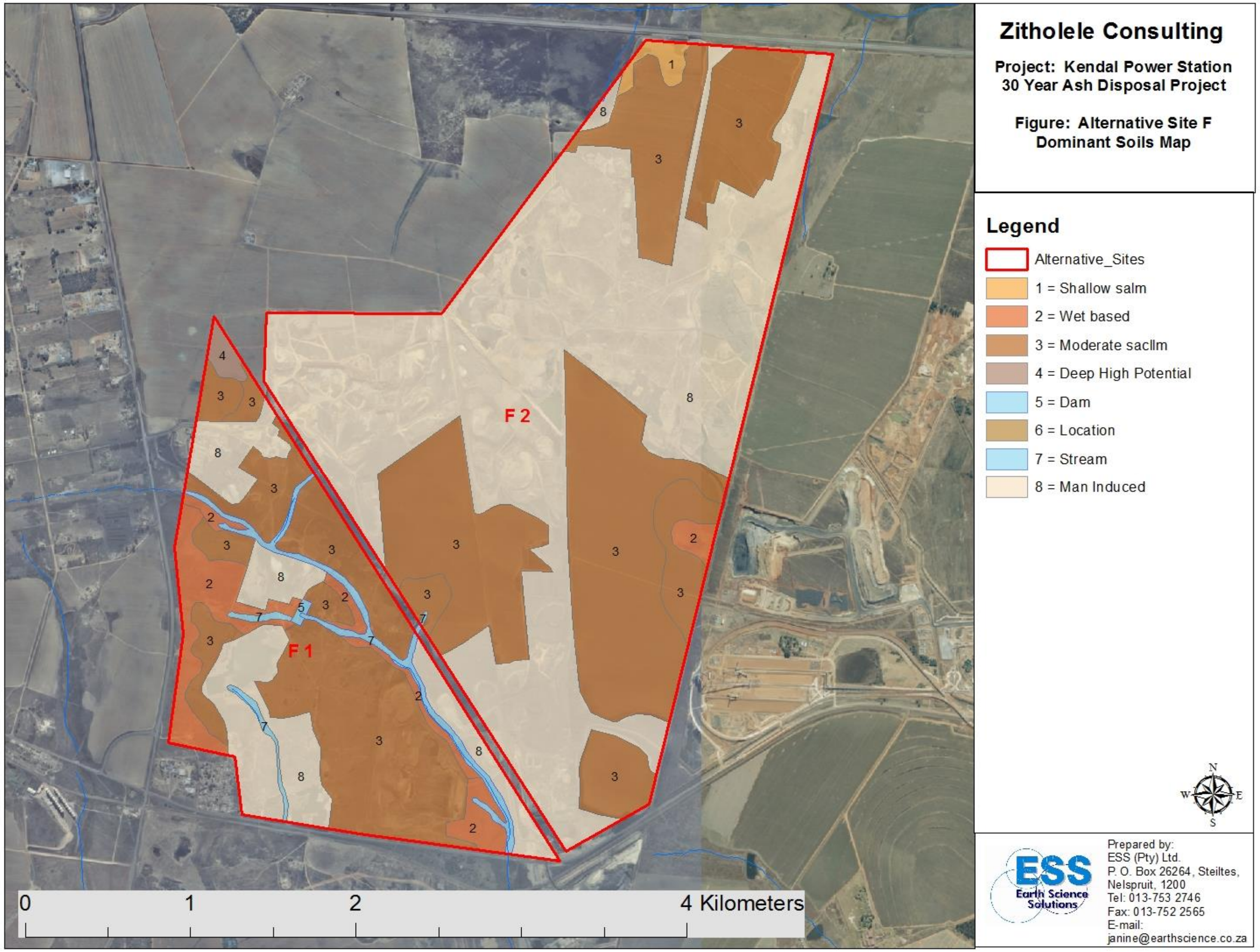

Figure 2.1.2e - Dominant Soils Map – Proposed Ash Disposal Facility Site F

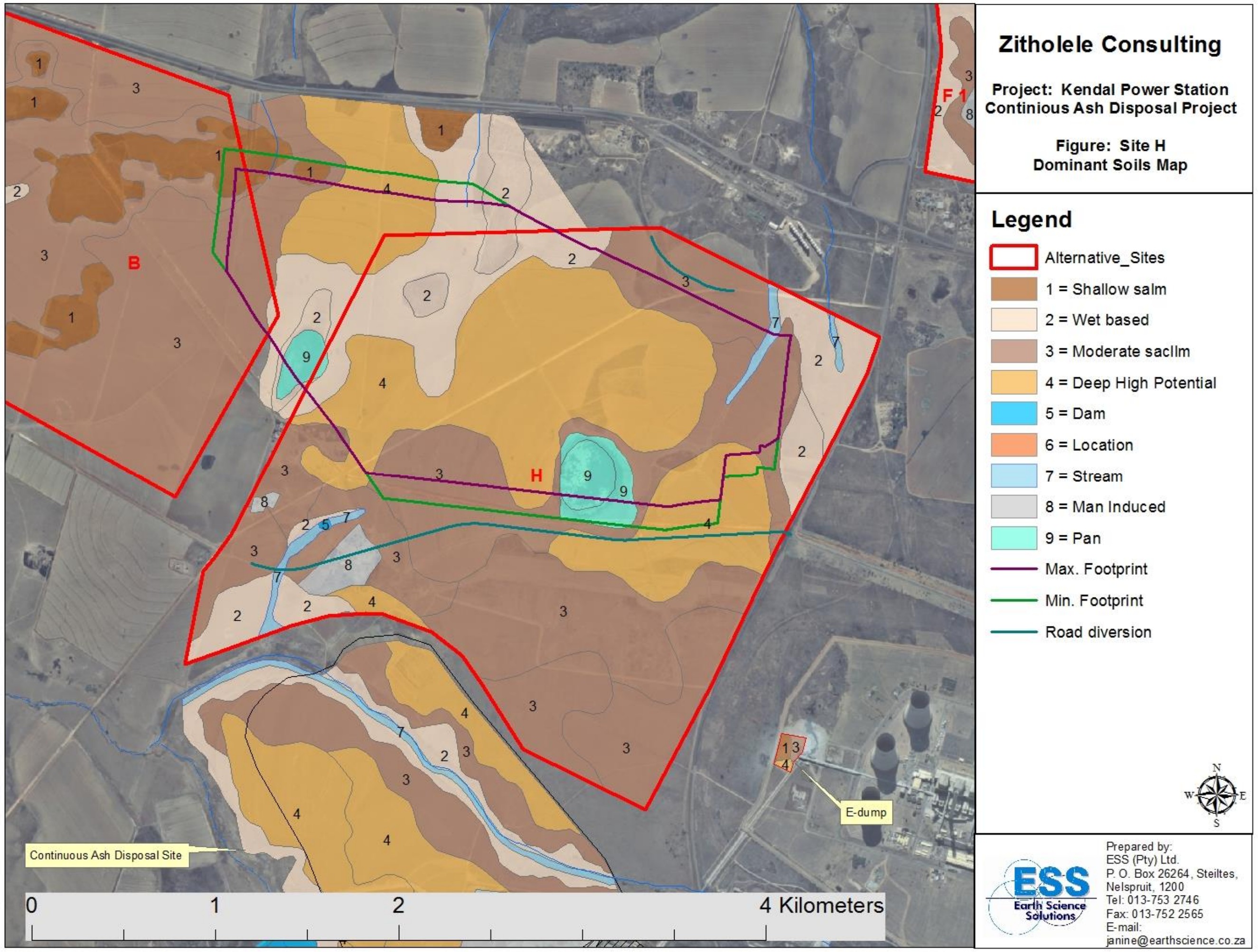

Figure 2.1.2f - Dominant Soils Map – Proposed Ash Disposal Facility Site H

Again, it is noted as important to the baseline study, that these soil groupings are moderately extensive in spatial area, and cover a moderately large and sensitive area in terms of the proposed development plan.

- In addition, but not separated from the wet based structured soils are the group of soils that reflect ***wetness*** within the top 500mm. These soils are easily recognised by the mottled red and yellow colours on low chroma background. These soils are regarded as ***highly sensitive*** zones that will require authorisation/permission if they are to be impacted. The legal implications (licensing) will need to be considered if these soils are to be impacted.

  The concentrations of natural salts and stores of nutrients within these soils are again a sensitive balance due to the extremes of rainfall, wind and temperature. The ability of a soil to retain moisture and nutrients, and in turn influence the sustainability of vegetative growth and affect the dependence of animal life is determined by the consistency and degree of soil moisture retention within the profile, and out of the influence of evaporation.

  These conditions and associated sensitivities should be noted in terms of the overall bio-diversity balance if the sustainability equation is to be managed and mitigation engineered. The shallow wet based soils are an important contributor to the ecological cycle.

All areas included in the study have been captured in a GIS format and mapped according to their soil classification nomenclature and soil depth (decimetres), while the similar soil forms have been grouped and mapped as dominant groupings for ease of management.

2.1.3 Soil Chemical and Physical Characteristics

Based on the previous investigations and environmental assessments undertaken for the area, and with a significant amount of baseline chemistry available for the site section process undertaken, the soil chemistry was obtained from existing studies of the soils on land in close proximity to the areas of concern. This information is available from soil studies that were executed during the mining right applications and as part of the MPRDA Process for coal mining projects adjacent to or on the land in question.

2.1.3.1 Soil Chemical Characteristics

The results are indicative of the pre-construction conditions and are representative of the baseline conditions only. It is important to remember that the soils will change while in storage, and the results tabled here will need to be verified for particular sites as and when rehabilitation is started.

On-going sampling and monitoring of the in-situ conditions will be necessary throughout the operational phase to accurately define the post operational conditions if the rehabilitation is to be successful.

The results of the laboratory analysis returned a variety of materials that range from very well sorted sandy loams with lower than average nutrient stores and moderate clay percentages (<20% - B2/1), to soils with a moderately stratified to weak blocky structure, sandy loam to clay loam texture and varying degrees of utilizable, while the nutrient stores on the colluvial derived materials, and the extremes of much higher clay and stronger structure that are noted on the wet based and wetland soils, returned lower than average nutrient concentrations and better than average water holding capabilities.

In general, the pH ranges from acid at 5.8 to neutral and slightly alkaline at 7.5, a base status ranging from 5.2me% to 22.8me% [Mesotrophic (moderate leaching status) to Dystrophic (Highly leached)], and nutrient levels reflecting generally acceptable levels of calcium and magnesium, but deficiencies in the levels of potassium, phosphorous, and zinc. The organic carbon matter is reflective of the semi-arid environment.

The more structured (moderate blocky) and associated sandy and silty clay loams returned values that are indicative of the more iron rich materials and more basic lithologies that have contributed to the soils mapped. They are inherently low in potassium reserves, and returned lower levels of zinc and phosphorous.

The growth potential on soils with these nutrient characteristics is at best moderate to poor and additions of nutrient and compost are necessary if commercial returns are to be achieved from these soils. They are at best moderate to good grazing lands.

Table 2.1.3.1 Analytical Results

Sample No.	**CA1**	**CA2**	**CA3**	**CA4**	**CA5**	**CA6**	**CA8**	**EEP15**	**EEP19**	**ED1**	**ED2**	Optimum Range
Soil Form	**Cv**	**Av**	**Gc**	**Pn**	**Ka**	**Hu**	**Kd**	**Sd/Hu**	**Rg**	**Dr**	**We**	
Constituents mg/kg												
pH	6.25	6	5.5	6.5	5.2	6.4	6.4	6	5.5	6.1	6.4	5.2 - 6.5
"S" Value	11.2	8.9	22.1	14.8	31	11	22	22.8	33	5.2	5.8	
Ca Ratio	59	70	66	65	62	65	49	68	62	70	65	55-75
Mg Ratio	16	24	30	32	34	22	28	34	34	28	10	18-30
K Ratio	18	4	1	1	7	4	8	4	9	0.6	12	6-10
Na Ratio	0.2	0.3	0.2	1.6	1.1	0.5	0.3	0.4	0.8	1.4	0.2	
P	111	22	8	6	17	10	15	12	20	5	82	20 -80
Zn	7.2	2	1	1.1	1.4	1.5	1.4	2	1.1	1	1.6	2-10
Sand	45	42	34	46	18	52	21	42	16	58	44	
Silt	39	36	38	46	22	30	27	26	26	34	35	
Clay	16	22	28	8	60	18	52	32	58	8	21	15 -25
Organic Carbon %	0.15	0.32	0.45	0.12	0.75	0.45	0.6	0.8	0.2	0.15	0.2	>0.75

Soil fertility

The soils mapped returned at best moderate levels of some of the essential nutrients required for plant growth with sufficient stores of calcium and magnesium. However, levels of Na, Zn, P, and K are generally lower than the optimum required. These conditions are important in better understanding the land capability ratings that are recorded, with the majority of the study area being rated as low intensity grazing land.

These poor conditions for growth were further compounded by the low organic carbon (< 0.75%).

There are no indications of any toxic elements that are likely to limit natural plant growth in the soils mapped within the study area

Nutrient Storage and Cation Exchange Capacity (CEC)

The potential for a soil to retain and supply nutrients can be assessed by measuring the cation exchange capacity (CEC or "S" Values) of the soils.

The inherently low organic carbon content is detrimental to the exchange mechanisms, as it is these elements which naturally provide exchange sites that serve as nutrient stores.

The moderate clay contents will temper this situation somewhat with at best a moderate to low retention and supply of nutrients for plant growth.

Low CEC values are an indication of soils lacking organic matter and clay minerals. Typically a soil rich in humus will have a CEC of 300 me/100g (>30 me/%), while a soil low in organic matter and clay may have a CEC of 1 me/100g to 5 me/100g (<5 me/%).

Generally, the CEC values for the soils mapped in the area are moderate.

Soil organic matter

The soils mapped are generally low in organic carbon. This factor coupled with the moderate to high clay contents for the majority of the soils mapped will adversely affect the erosion indices for the soils.

2.1.3.2 Soil Physical Characteristics

The majority of the soils mapped exhibit apedal to weak crumby structure, low to moderate clay content and a dystrophic leaching status. The texture comprises sandy to silty sands for the most part, with much finer silty loams and clay loams associated with the colluvial and alluvial derived materials associated with the lower slope and bottom land stream and river environs respectively.

Of significance to this study, and a feature that is moderately common across the three sites where the soils are associated with the sedimentary host rocks (albeit that it often occurs below the 1.5m auger depth on the deeper soils) is the presence of a soft plinthic or hard pan ferricrete (plinthite) layer within the soil profile.

The semi-arid climate (negative water balance) combined with the geochemistry of the host rock geology are conducive to the formation of evaporites, with the development of ferruginous layers or zones within the vadose zone. The accumulation of concentrations of iron and manganese rich fluids in solution will result in the precipitation of the salts and metals due to high evaporation (negative water balance). This process results in the development of a restrictive or inhibiting layer/zone within the profile over time.

The negative water balance is evidenced by the generally low rainfall of 800mm/year or less, and the high evaporation that averages 1,350mm/year. These are the driving mechanisms behind the ouklip or hard pan ferricrete mapped.

The degree of hardness of the evaporite is gradational, with soft plinthic horizons (very friable and easily *dug with a spade or shovel),* through hard plinthite soil *(varying in particle size from sand to gravel – but no cementation)* to nodular and hard pan ferricrete or hard plinthic *(cementation of iron and manganese into nodules)* that are not possible to free dig or brake with a shovel.

This classification is taken from - Petrological and Geochemical Classification of Laterites -*Yves Tardy, Jean-Lou, Novikoff and Claude Roquid,* and forms the basis for classify the hard pan ferricrete or lateritic portion of the soil horizon in terms of its workability (engineering properties) and storage sensitivities.

The soil classification system takes cognisance of ferricrete and has specific nomenclature for these occurrences (Refer to The South African Taxonomic Soil Classification – See list of references).

The variation in the consistency of the evaporite layer, its thickness and extent of influence across/under the site are all important to the concept of a restrictive horizon or barrier layer that is formed at the base of the soil profile and/or close to the soil surface.

Where this horizon develops to a nodular form or harder (Nodular, Honeycomb and Hard Pan) the movement of water within the soil profile is restrict from vertical movement and is forced to move laterally or perch within the profile. It is this accumulation of soil water and the precipitation of the metals from the metal and salt rich water that adds progressively to the ferricrete layer over time.

Important to an understanding of the development of the ferricrete is the geological time and presence of the specific soil and water chemistry under which the horizon forms. This situation will be very difficult to emulate or recreate if impacted or destroyed.

2.1.4 Soil Erosion and Compaction

Erodibility is defined as the vulnerability or susceptibility of a soil to erosion. It is a function of both the physical characteristics of a particular soil as well as the treatment of the soil.

The resistance to, or ease of erosion of a soil is expressed by an erodibility factor ("K"), which is determined from soil texture/clay content, permeability, organic matter content and soil structure. The Soil Erodibility Nomograph (*Wischmeier et al,* 1971) was used to calculate the "K" value.

With the "K" value in hand, the index of erosion (I.O.E.) for a soil can then be determined by multiplying the "K" value by the "slope" measured as a percentage. Erosion problems may be experienced when the Index of Erosion (I.O.E) is greater than 2.

The majority of the soils mapped can be classified as having a moderate to high erodible erodibility index in terms of their organic carbon content and clay content, albeit that this rating is off-set and tempered to a rating of moderate or low by the undulating to flat terrain.

However, the vulnerability of the "B" horizon to erosion once the topsoil and/or vegetation is removed must not be under estimated when working with or on these soils. These horizons (B2/1) are vulnerable and rate as medium to high when exposed.

The concerns around erosion and inter alia compaction, are directly related to the disturbance of the protective vegetation cover and topsoil that will be disturbed during any construction and operational phases of the development venture. Once disturbed, the effects and actions of wind and water are increased.

Loss of soil (topsoil and subsoil) is extremely costly to any operation, and is generally only evident at closure or when rehabilitation operations are compromised.

Well planned management actions during the planning, construction and operational phases will save time and money in the long run, and will have an impact on the ability to successfully "close" an operation once completed.

2.2 Pre-Construction Land Capability

2.2.1 Data Collection

Based on a well-developed and scientifically founded baseline of information, the South African Chamber of Developments (1991) Land Capability Rating System in conjunction with the Canadian Land Inventory System has been used as the basis for the land capability study.

Using these systems, the land capability of the study area was classified into four distinctly different and recognisable classes, namely, wet land or lands with wet based soils, arable land, grazing land and wilderness or conservation land. The criteria for this classification are set out in Table 2.2.1.

Table 2.2.1 Criteria for Pre-Construction Land Capability (S.A. Chamber of Developments 1991)

Criteria for Wetland

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

Criteria for Arable Land

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

Criteria for Grazing Land

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

Criteria for Conservation of Land

Land, which does not qualify as having wetland soils, arable land or grazing land, and as a result is regarded as requiring conservation practise/actions.

2.2.2 Description

The “land capability classification” as described above was used to characterise and classify the soil polygons or units of land identified during the pedological survey.

These combined with the geomorphological aspects (ground roughness, topography, climate etc.) of the site were then employed to rate the capability of the land in question.

The area to be disturbed by the proposed ash deposition and its surface infrastructure development comprises a range of land capability classes, with significant areas of friable and good grazing potential class soil, smaller areas or good arable potential materials and significant areas associated with the lower lying areas topographically of highly sensitive sites that returned wet based soils. The colluvial derived soils are at best considered to have a low intensity grazing land potential or wilderness status.

Figure 2.2.2a through 2.2.2e illustrates the distribution of land capability classes across the study areas.

Arable Land

The arable potential for the majority of the soils mapped is low unless substantial quantities of fertiliser and manure are added. Some soil depths are reflective of a arable status (>750mm), however, the growth potential (nutrient status and soil water capabilities) and ability of these soils to return a cropping yield equal to or better than the national average is lacking. This is due mainly to the poor rainfall and less than optimum nutrient status of many of the soils. These variables reflect the natural conditions, and do not include any man induced additives such as fertilizers or water.

Grazing Land

The classification of grazing land is generally confined to the shallower and transitional zones that are well drained. These soils are generally darker in colour, and are not always free draining to a depth of 750mm but are capable of sustaining palatable plant species on a sustainable basis (only the subsoil’s at a depth of >500mm are periodically wetted). In addition, there should be no rocks or pedocrete fragments in the upper horizons of this soil group. If present it will limit the land capability to wilderness land.

The majority of the study area classifies as low intensity grazing land or wilderness status.

Wilderness / Conservation Land

The shallow rocky areas and soils with a structure stronger than strong blocky (vertic etc.) are characteristically poorly rooted and support at best very low intensity grazing, or more realistically are of a Wilderness character and rating.

Wetland (Areas with wetland status soils)

Wetland areas in this document (soils and land capability) are defined in terms of the wetland delineation guidelines, which use both soil characteristics, the topography as well as floral and faunal criteria to define the domain limits (Separate Wetland Delineation has been undertaken). Only the soils are described here.

These zones (wetlands) are dominated by hydromorphic soils (wet based) that often show signs of structure, and have plant life (vegetation) that is associated with seasonal wetting or permanent wetting of the soil profile (separate study).

The wetland soils are generally characterised by dark grey to black (organic carbon) in the topsoil horizons and are often high in transported clays and show variegated signs of mottling on gleyed backgrounds (pale grey colours) in the subsoil's. Wetland soils occur within the zone of soil water influence.

A significant but relatively small proportion of the study area classifies as having wet based soils. However, it is important to note that a significantly large area of the open pit and infrastructure development being planned encroaches on soils with a wet base.

These should not be mistaken as wetlands in terms of the delineation document, but should be highlighted as potential zones of sensitivity with the potential for highly sensitive areas associated with the prominent waterway associated with the development area.

These zones are considered very important, highly sensitive and vulnerable due to their ability to contain and hold water for periods through the summers and into the dry winter seasons.

2.3 Agricultural Potential Assessment

2.3.1 Background Information and System

The candidate site (Site H) was highlighted in the soil and land capability studies as an area of interest based on the spatial extent and distribution of deep well drained soils, and the land use noted in the form of significant areas of irrigated land (Centre Pivot Irrigation).

In assessing the merits of the area delineated for development it was considered prudent that the agricultural potential was understood and documented as part of the baseline of information. Food security and an understanding of the eco system services that could be impacted and/or lost are issues that need to be captured as part of the significance rating.

The system employed included a more detailed assessment of the geomorphology of the site and the collection of more scientific data from laboratory analysis. This information has been used to assess and rate the “Agricultural Potential” (AP) of the area using the Agricultural Suitability Rating (ASR) System as tabled below (Table 2.3a).

The additional scientific information obtained from the analytical analysis detailed the physical and chemical variations of the soils, while topographic and ground roughness were noted in conjunction with any geological changes as part of the geomorphological characterisation. These aspects were mapped as dominant soils (Refer to Figure 2.3.2a), while the Agricultural Potential is depicted in Figure 2.3.3.

Ideally, soils used for economic agricultural production should satisfy the following conditions:

- Moderate uniformity
- Good rooting depth (>700mm)
- Low rockiness hazard (<20%)
- Moderate permeability
- Good supply of available moisture (T.A.M.C. >70mm/m)
- Satisfactory aeration and infiltration rates (>8mm/hr)
- Moderate resistance to erosion
- Salinity and exchangeable sodium levels should be less than 200 milli-Siemens per meter (mS/m) and 2 milli-equivalents per hundred grams (me/100g).

Applying these criteria where possible to the soils that were mapped, a scale of Agricultural Suitability (AS) based on the limitations of the above factors has been defined for the varying soil groups, thus assisting in the determination of the agricultural potential of the site. The system used is shown Table 2.3a below, while the analytical results for the additional soil samples assessed are tabled in Table 2.3b.

The ASR was included as part of the overall baseline of information that has been used in the Impact Assessment and determination of the management measures.

It is considered pertinent that this variable (Agricultural Potential) is better understood in terms of both the eco system services that will be lost as well as the mitigation that needs to be considered.

Table 2.3a: Suitability Ratings

Suitability Unit	Rating No.	Soil depth & Soil Forms	Degree of Limitation	Management Needs
AO; BO	Very good (1)	>10Hu, Cv, Gf	None	Very good irrigation
BO; A1; B3:4	Good (2)	>8Hu, Cv, Sd, Gf, Oa	Slight Moist Limit Slight Erosion Hazard.	Good Irrigation Soils Good Conservation
A2; B1, B2; B3:4; CO:2	Moderate (3)	>6Hu, Cv, Gf, Oa, Sd, Pn, Va, Se	Moderate depth Low T.A.M.C. Erosion Hazard = Moderate	Irrigation. Small amounts of water more frequent
C2: D1x1: D1x:4, D2;3	Poor (4)	<600 but >400mm of any soil form	Severe, depth erosion, with signs of wetness	Not good. Unsuitable to Irrigation Dryland Pastures
D2; C1 x D3: 4E	Unsuitable (5)	All wet and very shallow soils	Very severe depth limit, wetness and erosion	Dryland Pastures Not Recommended for Irrigation

Highlighted area = excluded from irrigation development

Suitability Grades

A - Excellent	0 - No major limitations
B – Good	1 - Slight salinity or water logging hazard
C – Fair	1x - Marked salinity or water logging
D – Poor	2 - Shallow soil depth
E - Unsuitable	3 - Surface capping / rusting
	4 - Severe erosion hazard

The ratings vary from very good to unsuitable as the degree of limitation progressively becomes more severe.

Table 2.3b: Analytical Results – Soils

SOIL STANDARD ANALYSIS

Sample No	pH(water)	Res(ohms)	Ca mg/kg	Mg mg/kg	K mg/kg	Na mg/kg	P (Bray1)	Al mg/kg	Ca/Mg	Ca+Mg/K	CEC cmol(-)/kg
482	5.05	2200	286	87	204	6	6.5	25	3.29	1.83	2.97
487	5.02	1800	425	74	89	55	13.8	30	5.74	5.61	3.53
490	4.87	2000	204	52	65	7	9.1	59	3.92	3.94	2.30
491	6.27	3500	409	70	54	3	41.6	11	5.84	8.87	2.89
492	5.38	2100	273	58	58	5	40.0	23	4.71	5.71	2.27
495	5.76	400	513	120	412	193	26.9	13	4.28	1.54	5.59
496	5.84	1500	506	105	186	19	24.5	17	4.82	3.29	4.14
500	6.13	2500	507	86	55	16	18.4	7	5.90	10.78	3.53
509	5.62	2000	407	112	74	28	5.1	9	3.63	7.01	3.36
516	6.28	1400	748	130	141	24	54.3	9	5.75	6.23	5.37
520	6.11	1900	316	84	68	11	10.7	10	3.76	5.88	2.60
524	4.64	1700	282	53	99	8	22.7	45	5.32	3.38	2.63

Sample No	Zn mg/kg	Fe mg/kg	C %	Org Mat %	Sand %	Silt %	Clay %
482	8.70	86.4	0.98	1.68	78	7	15
487	3.69	303.1	0.9	1.65	76	7	17
490	5.56	74.1	0.59	1.01	80	7	13
491	14.64	64.2	0.47	0.80	82	5	13
492	2.87	88.5	0.31	0.54	82	5	13
495	6.30	76.4	0.66	1.14	80	3	17
496	42.99	90.5	1.17	2.01	68	9	23
500	2.24	71.2	0.85	1.45	86	3	11
509	2.77	75.2	0.66	1.14	74	7	19
516	9.15	88.3	0.95	1.68	74	7	19
520	3.87	154.1	0.65	1.14	78	5	17
524	3.16	79.4	0.55	0.98	74	9	17

2.3.2 Soil Descriptions

In the course of the soil survey a number of differing soil forms were mapped. These included:

Clovelly (Cv), Hutton (Hu), Glencoe (Gc), Dresden (Dr) and Glenrosa (Gs), so well as the more hydromorphic Forms, namely Avalon (Av), Westleigh (We) and Pinedene (Pn).

The distribution of the dominant soils mapped/classified is shown graphically below in Figure 2.3.2a and the Agricultural Potential in Figure 2.3.3.

The dominant soil mapped and classified have been described below in more detail, with consideration of the soil physical and chemical properties and the overall geomorphology (climate, topography, ground roughness and geology) being included in better understanding the agricultural potential and spatial distribution across the area of study.

Hutton (Hu) and Clovelly (Cv)

The Hutton and Clovelly soil Forms returned results that have an average rooting depth (ERD) of between 400mm and 1,200mm on average, generally have a fine to medium grained texture and sand fraction, and in the majority of cases mapped they exhibit structure that is apedal to single grained.

These soils are generally confined to the middle and lower-mid slope positions adjacent to and up slope of the Avalon and Pinedene Forms.

The physical characteristics of these soils are fairly well drained. Overall they returned moderate to high intake rates (10 to 13mm/hr), coupled with moderate to low TAM, ranging from 36mm/m on the shallower sandy soils to over 95mm/m on the heavier deeper soils, have moderate to good internal drainage and moderate to high compactability.

With these characteristics the soils can be described as moderate to good on the Agricultural Suitability Rating (A.S.R.) scale namely B-0 to A-1 and are of the better agricultural soils mapped in the area. Restrictions at depth to drainage are evident in some of the profiles mapped at the B/C interface, often on what appears to be a hard plinthic or saprolitic layer. Erosion is generally not a major problem, but needs to be monitored with respect to the relief of the site, and will definitely increase in severity (increase in the erosion index) if the vegetative cover is disturbed or removed.

Chemically, these soils returned lower than average amounts of the essential nutrients needed for adequate growth regimes, albeit that the Ca/Mg ratio is good, and the levels of Zinc (Zn), iron (Fe) and Aluminium (Al) are adequate. The pH readings of between 4.6 and 6.2 render these soils acid in character.

RECOMMENDATION: Suitable for most agricultural development if sufficient water is made available. Good irrigation/water management would be needed if these lands were to be considered for irrigated pastures or economic dryland cultivation. The depth of rooting is considered moderate to good in terms of commercial agricultural.

Mispah (Ms) and Glenrosa (Gs)

The Mispah and Glenrosa soil Forms returned effective rooting depths (ERD) of between 100mm and 400mm. The major hazards encountered with these soil types is erosion and loss of the eco system services due to the shallow ERD, the poor vegetative cover and the rockiness of some of the areas.

A layer of trash or grass should be left covering the surface and the minimum tillage system should be employed if these soils are to be cultivated. Tillage constraints are moderate due to machine wear and subsurface hindrance (rocks etc. in the profile).

Geophysical, the soils returned moderate clay percentages (12 25%), moderate intake rates (6 to 10mm/hr), low available moisture holding capacities (<40mm/m) and better than average drainage.

RECOMMENDATION: Unsuitable for any commercial agriculture due to the shallow and/or varying soil depth.

Glencoe (Gc) and Dresden (Dr)

The Glencoe and Dresden (Dr) soil Forms are associated with the more iron rich lithologies and sites with impaired drainage, the underlying ferruginous/hard pan ferricrete layer forming a barrier to the vertical movement of soil water.

These soils are considered sensitive to disturbance, with the storage of soil water within the vadose zone considered a positive contributor to the biodiversity and ecological functioning of the environment.

These soils are often associate with historical land surfaces in the region, particularly where they are derived from horizontally bedded sediments.

These soils returned poor intake rates (2 to 4mm/hr), have a low available moisture holding capability, are low in available nutrients and are considered sensitive to the removal of vegetative cover and topsoil disturbance with resultant increases in the erosion index if they are not well managed. These soil forms classify as “transitional” soils under the wetland delineation system where the hard plinthite is below 500mm and as wetland soils on shallow soils of 500mm and less.

Detailed sampling is recommended if they are to be planted and a high degree of irrigation management would be needed if they are to be considered for irrigated cropping.

RECOMMENDATION: Poor to Unsuitable Agricultural Potential Lands.

Cultivation for dryland grazing at best. Under irrigation these soils become wetter for prolonged periods, increase the level of vadose water and resulting in waterlogged conditions. These are of the more sensitive materials mapped and are considered of the poorer agricultural sites.

Pinedene (Pn), Avalon (Av) and Westleigh (We)

The Avalon and Pinedene soil Forms are associated with the lower lying areas and midslope seeps that are often associated with a change in the local geology, and where vertical flow of water within the vadose zone has been impeded.

These soils returned moderate to poor intake rates (4 to 8mm/hr), have a lower than average moisture holding capability, are generally moderate to poorly drained, especially in lower horizons and are prone to erosion on the steeper slopes.

On average, these soils tend to be low in available nutrients and a mesotrophic to dystrophic leaching status.

RECOMMENDATION: Poor to Unsuitable Agricultural Potential Land.

These soils are unsuitable for cultivation. Under irrigation these soils become wetter for prolonged periods resulting in waterlogged conditions.

2.3.3 Total Available Moisture Capability (T.A.M.C.)

The soil study and the resulting T.A.M.C.’s as measured, are confined to selected auger sites, while the chemistry has been assessed based on a suite of composite samples representative of the most dominant soils in the study area.

The outcomes are summarised in Table 2.3.3 below

Table 2.3.3: Total Available Moisture

Soil Name	Soil Code	Soil Depth (mm)	Water Holding capability (mm/m)	ERD (m)	% Intake	Agricultural Suitability Rating	Irrigation Suitability	ISR
Avalon	Av	400~600	58	0.6	80	Moderate	Fair / Good	C-2
Clovelly	Cv	600~900	75	0.7	90	Moderate to Good	Good	B-2
Clovelly	Cv	400~600	48	0.6	60	Moderate	Fair	A-1
Glencoe	Gc	400~600	55	0.6	65	Moderate	Fair	B-0
Glencoe	Gc	200~400	42	0.4	40	Moderate to Poor	Fair	C 1x
Glencoe/Clovelly	Gc/Cv	600~800	68	0.7	80	Moderate to Good	Good	B-1
Glenrosa	Gs	200~400	38	0.4	50	Poor/Unsuitable	Fair	C-2
Glenrosa/Clovelly	Gs/Cv	200~400	36	0.4	65	Moderate to Poor	Fair	C-2
Westleigh	We	200~400	60	0.4	45	Unsuitable	Poor	E1x
Mispah	Ms	0~200	32	0.2	50	Unsuitable	Poor	E1x
Hutton	Hu	700~1200	85	1.0	110	Good	Good	B0/A0
TOTAL								

A.S.R. Explanation

A	Very high potential, well suited to irrigation	**0**	No major limitations
B	Generally well suited with high potential under irrigation	**1**	Slight salinity of water
C	Not as well suited owing to soil depth, drainage limitations – have a fair to moderate potential under drip irrigation.	**2**	Shallow soil depth
D	Generally not recommended, as soil limitations such as depth, drainage and or moisture retention may be severe – exceptionally good management is required if to be planted.	**3**	Surface crusting/capping
E	Should be avoided completely.	**4**	Severe erosion hazard

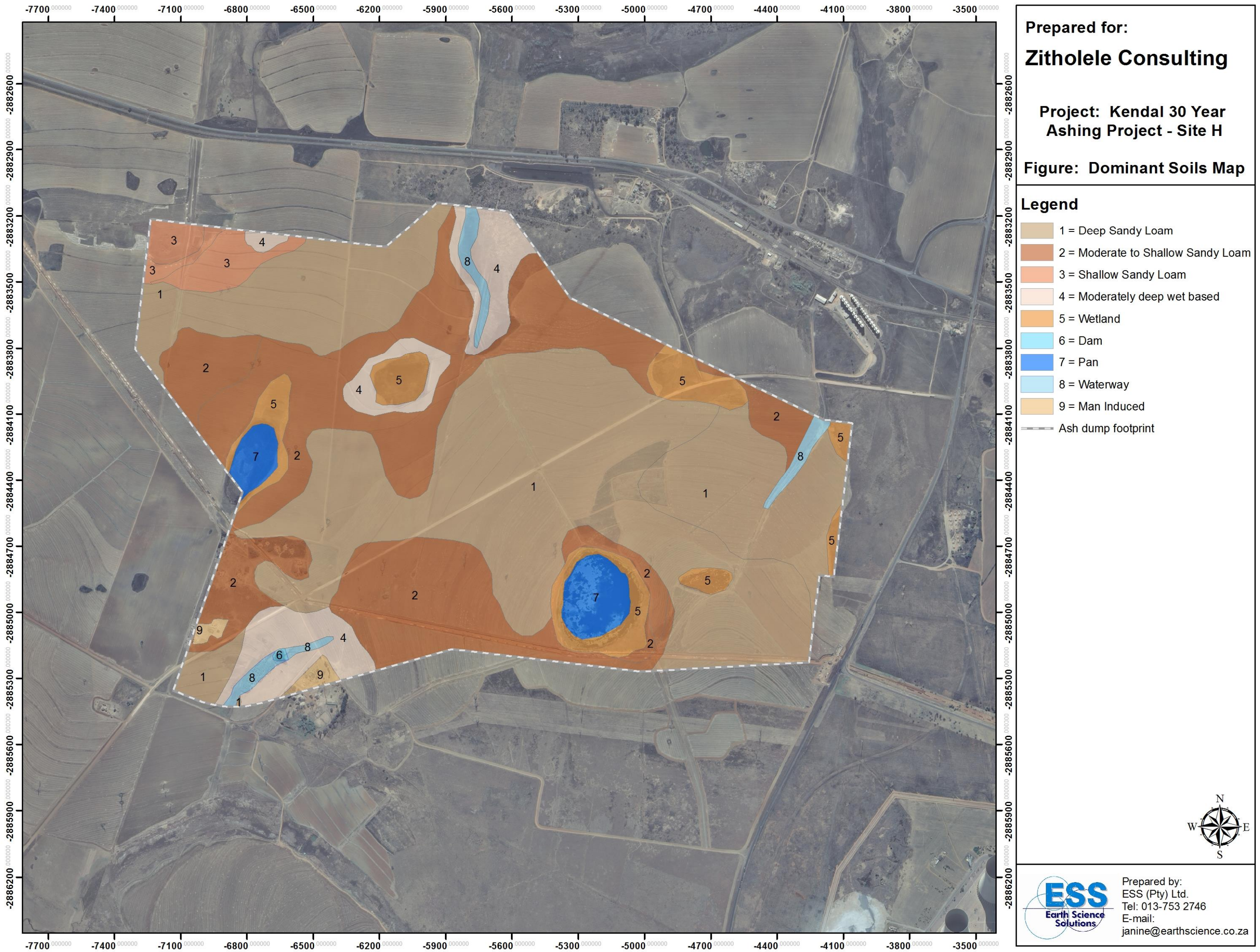

Figure 2.3.2a – Dominant Soils – Site H

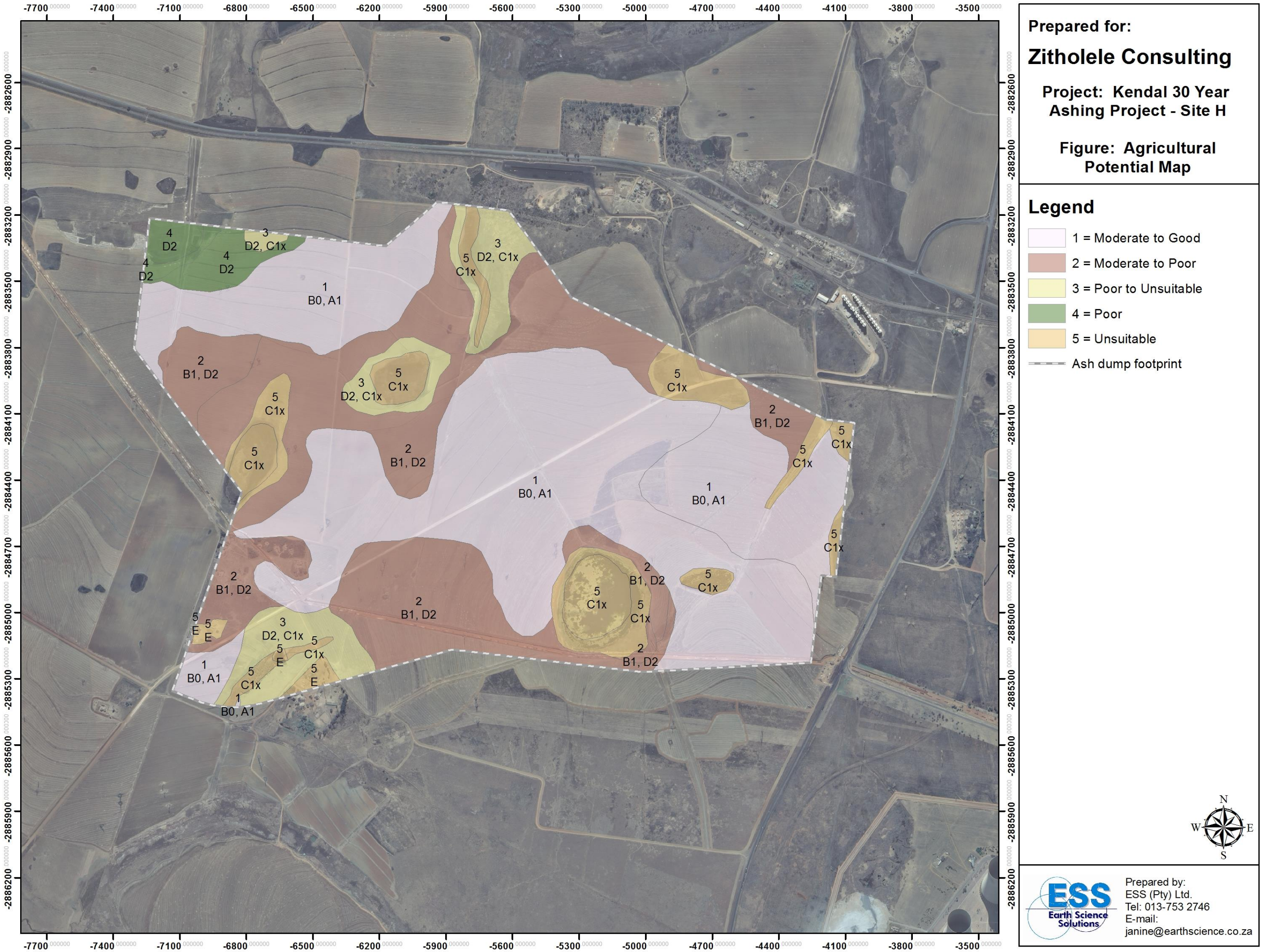

Figure 2.3.3a – Agricultural Potential Map

2.3.4 Conclusions

The foregoing chapters have focussed on aspects such as soil survey procedure, soil classification and mapping, and a description and classification of the soils in the area. In line with environmental considerations and best practise guidelines it is important that the lands capability is well understood before any development is considered for an area, with the agricultural potential a facet that speaks directly to the eco system services as well as the socio-economics of the environmental significance, and in turn the sustainability of a project,

Using the Agricultural Suitability Rating (A.S.R) as a measureable management variable, a value could be assigned to the agricultural potential for the area of concern. In determining the agricultural potential, the site has been rated on criteria such as unrestricted rooting depth (at least 700mm), a good supply of available water in the rooting zone (at least 700mm/m), satisfactory aeration and infiltration rate, no extremes of texture, low rockiness content and low levels of sodicity and salinity.

The Kendal 30 Year Ashing Project and Site H in particular is considered to be an important initiative for the area in terms of the power generation industry.

The Agricultural Potential of the land is however a concern in terms of the eco system services and security of food production for the country, and the socio economic aspects around job security and the sustainable utilisation of land.

Sites with an agricultural potential greater than "moderate" (Refer Table 2.3.4) are considered to be of value in terms of growing of certain food items (maize, soya etc.) and are rated as "arable" in terms of land capability.

Table 2 – Agricultural Potential

Agric_Pot	Agric_Pot1	Agric_Pot2	Total Area	% Area
1 = Moderate to Good	1	B0, A1	259.05	50.04
2 = Moderate to Poor	2	B1, D2	150.92	29.15
3 = Poor to Unsuitable	3	D2, C1x	36.13	6.98
4 = Poor	4	D2	14.67	2.83
5 = Unsuitable	5	C1x	56.88	10.99
Total			**517.65**	**100.00**

A significant proportion of the area of concern rates as moderate to good (50.04% or 259.05ha) in terms of agricultural potential, with an additional area that rates as good grazing potential land in terms of the land capability, and moderate to poor in terms of its agricultural (arable) potential (29.15% or 150.92ha). This additional area is considered less productive in terms of dryland cultivation for food crop items, but has a better than average rating for good quality livestock grazing potential under natural (no irrigation or fertilisation) conditions.

There is good evidence (present land use) to believe that an economically successful agricultural development is viable for a significant proportion (79.19%) of the study area, with better than average (national average for the crop climate) yields being returned from the moderate and good (50.04%) agricultural potential sites.

2.4 Alternative Assessment

Based on the field information gained from the reconnaissance studies and an understanding of the geomorphology of the sites, the land capability was rated. This information has been used as an aid in determining the site sensitivity (Refer to Figures 2.4a and 2.4 c – Sensitivity Maps and 2.4b and 2.4d – Land Capability) which in turn have been used to compare the three candidate sites. The ultimate decision on the most sustainable and environmentally correct site for the Ash Disposal Facility will require more than just an understanding of the soils and land capability.

Of consequence to any sustainability equation is the consideration of the soil resource, and the concept of “No Net Loss”, and although it is understood that this concept is seldom attainable for a development such as an Ash Disposal Facility (permanent structure), the concept is a good one and should be considered as a best practice limit to be aimed for wherever possible.

In considering the outcomes that have been used in measuring the alternatives for these studies the following variables were considered important:

Soils	Sensitivity of Soil
	Erosion Potential of Soil
	Soil Depth (ERD)
	Soil Structure and Workability
Land Capability	Arable Potential
	Grazing Potential
	Wilderness Potential
	Wetland Potential
Land Use	Presence of dwellings or people on the land
	Presence of Infrastructure
	Presence of livestock or cultivation on land

The ability of the earth scientist to assist the development and planners in obtaining the best alternative for a development is often found in the understanding of the interrelationship between the various disciplines.

A straight association is not always a true reflection of the sensitivity of a resource to impact, and might require that a weighting is attached to the particular aspect being considered. However, this is best left to the EAP as he/she has the cross section of the specialist information at hand.

Table 2.3 is a straight comparison of the three sites using a scale of 1 to 9, where 1 = Highly Suitable and 9 = Not Suitable, while Figure 2.3 is a graphic representation of the site sensitivities based primarily on soil and land capability variables.

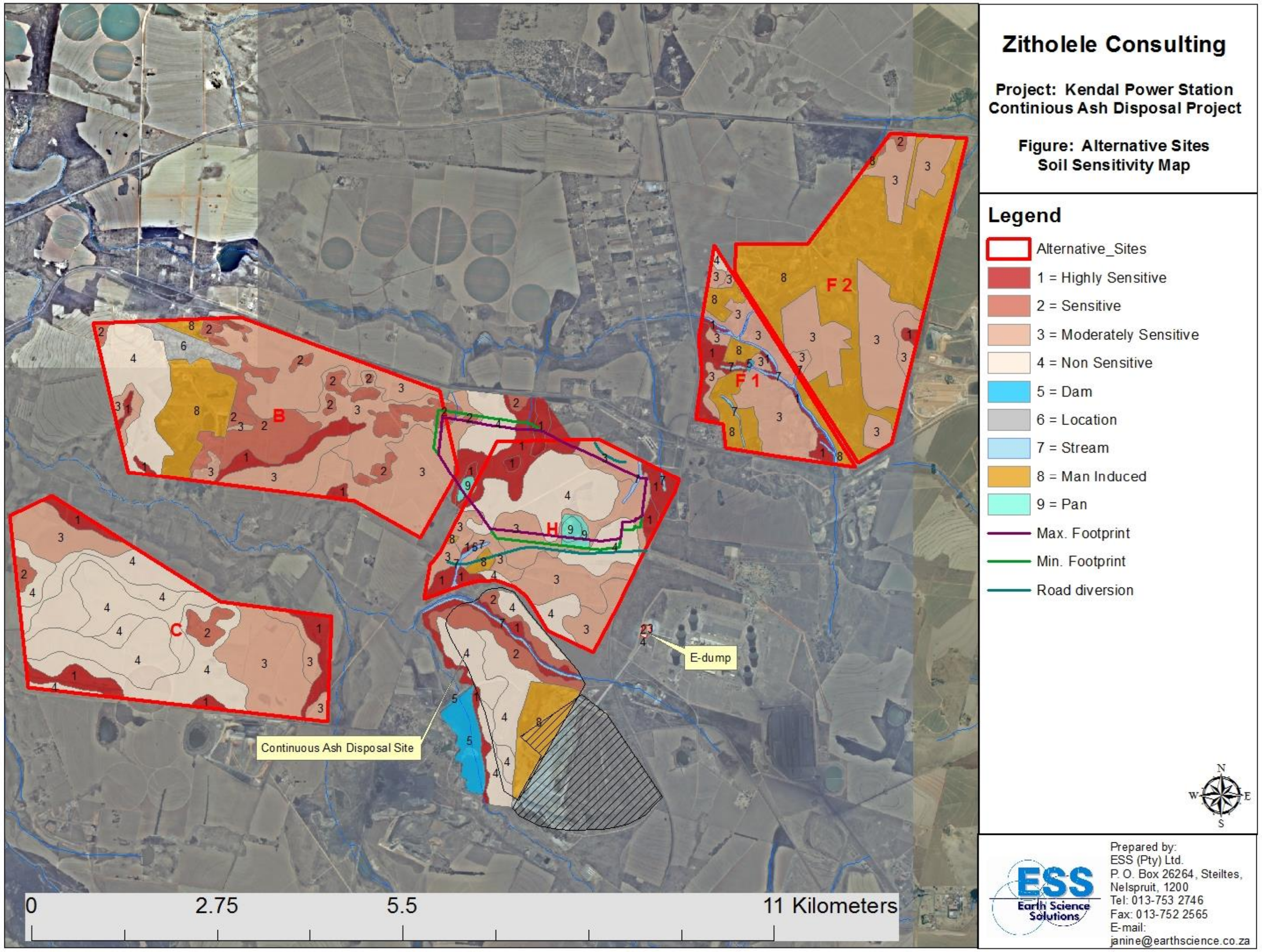

Figure 2.4a – Site Sensitivity Map – Proposed Ash Disposal Facility – Sites B, C F and H

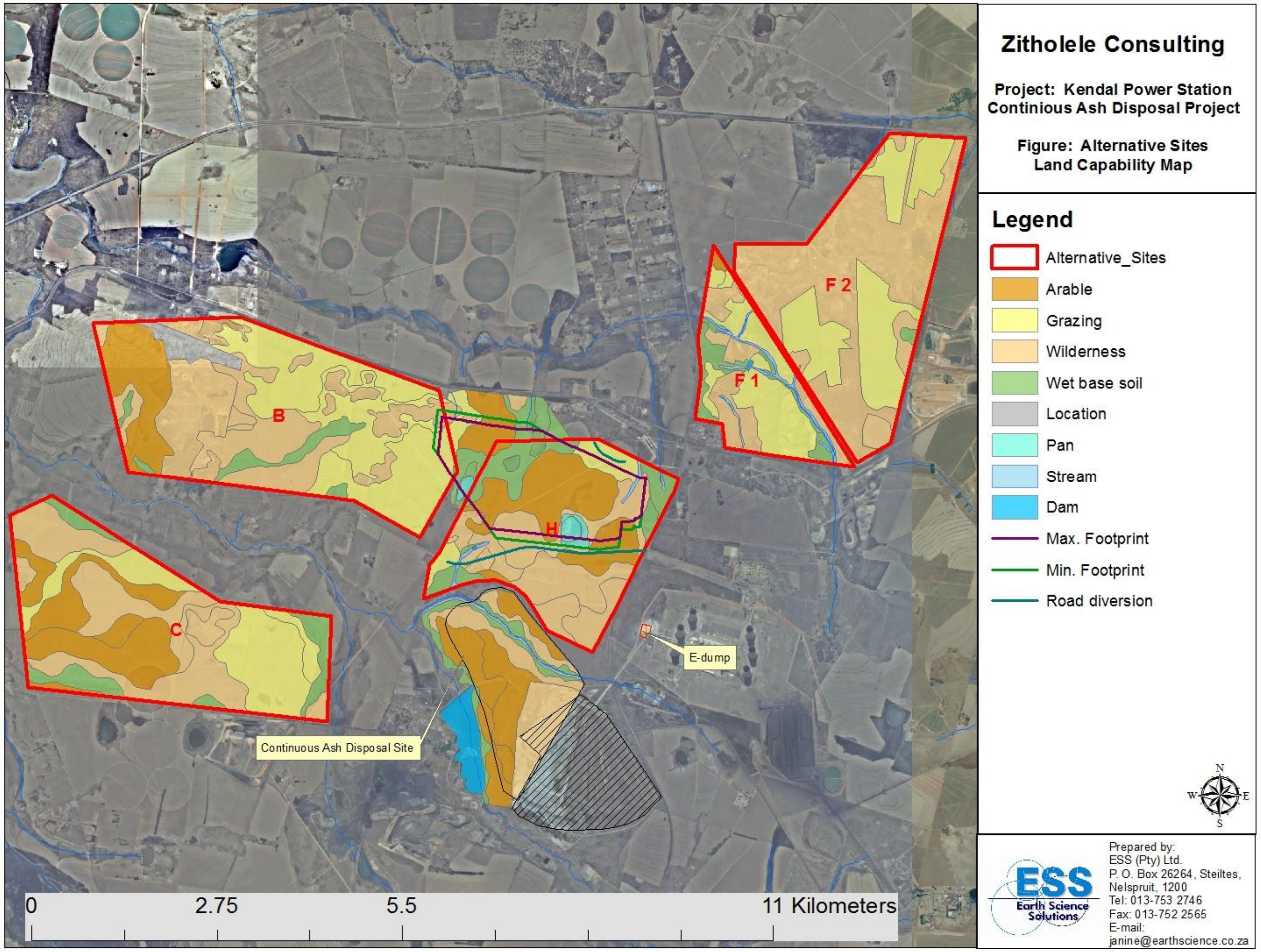

Figure 2.4b - Land Capability Map – Proposed Ash Disposal Facilities - Sites B, C F and H

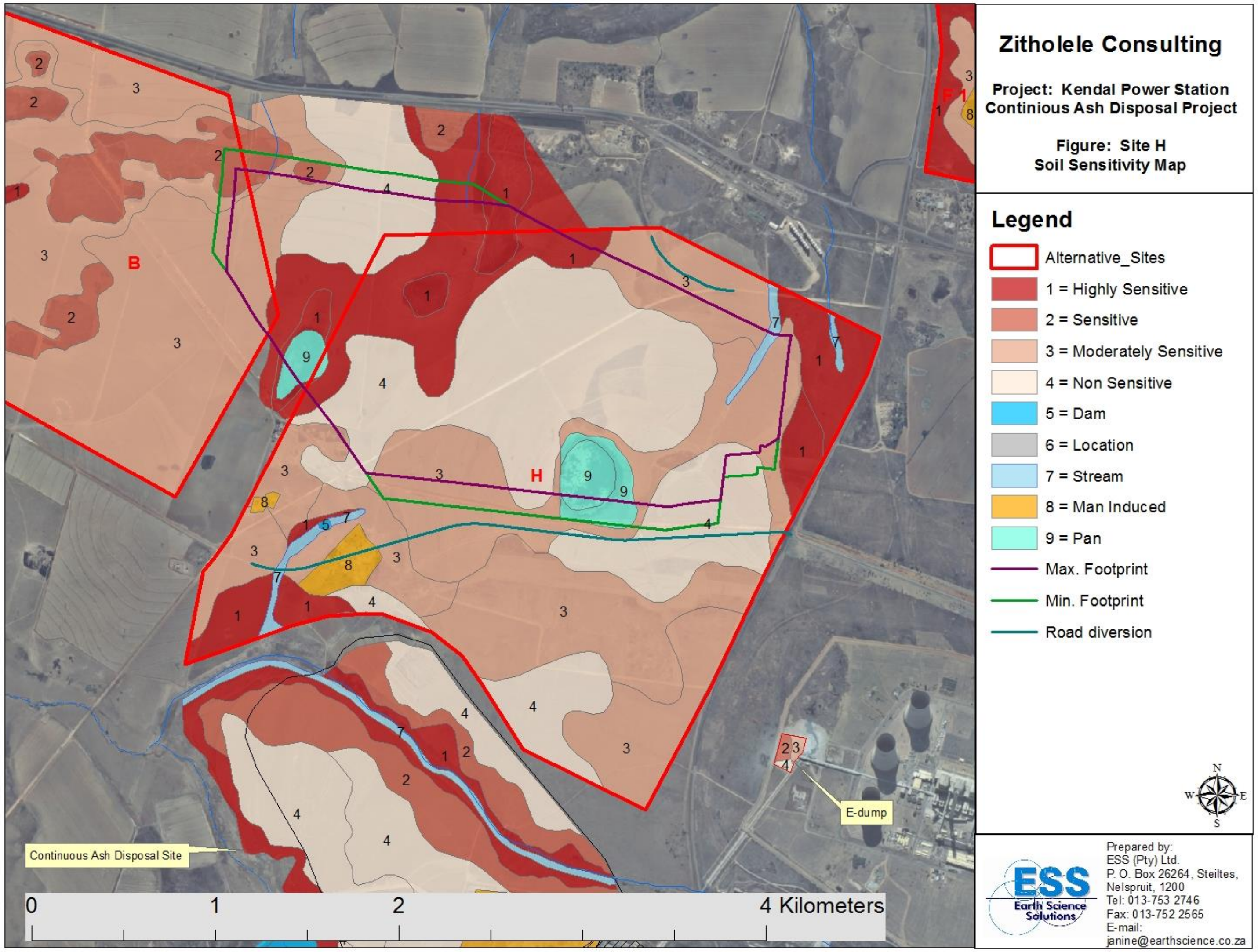

Figure 2.4c – Site Sensitivity Map – Proposed Ash Disposal Facility – Site H

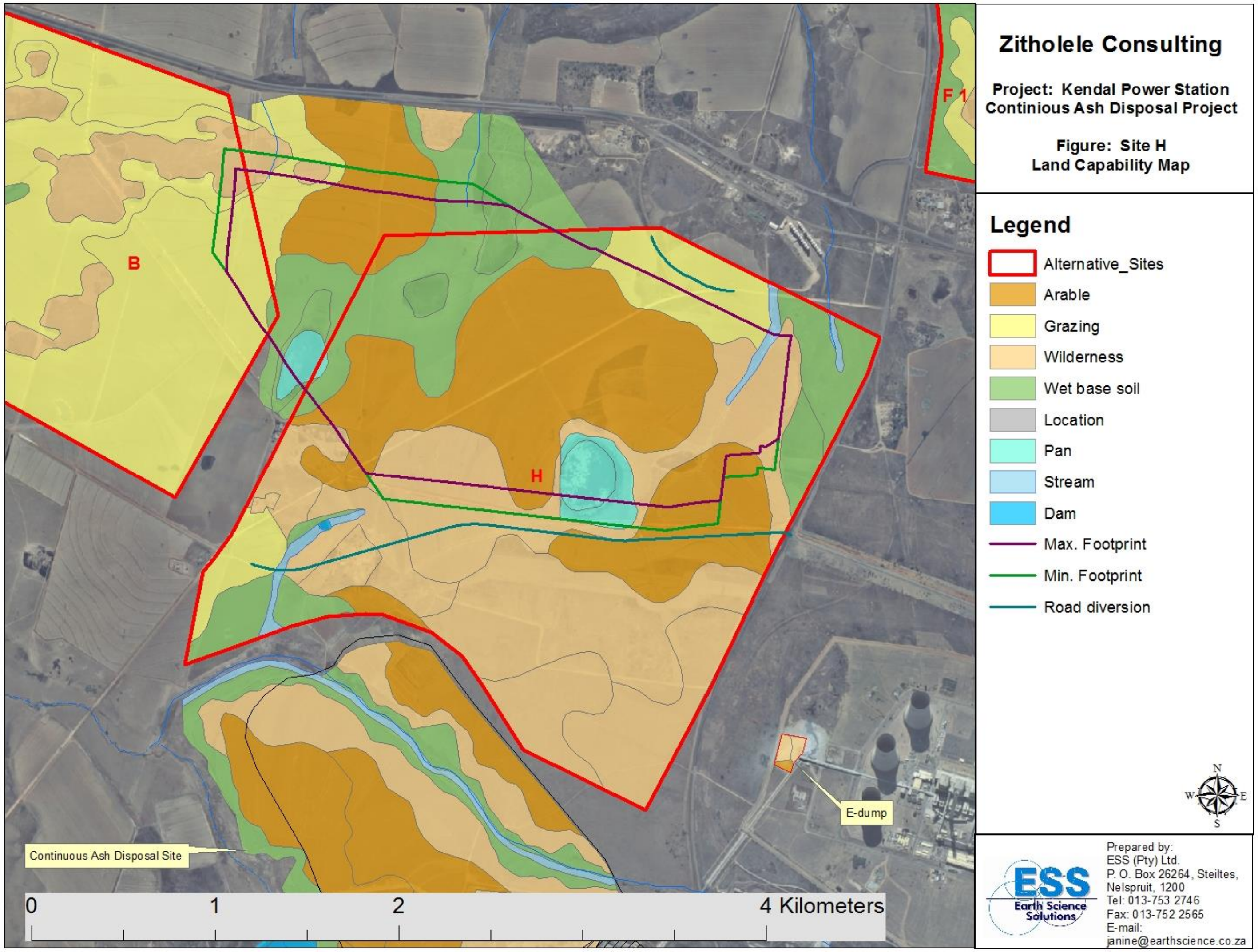

Figure 2.4d - Land Capability Map – Proposed Ash Disposal Facility – Site H

In summarising the outcomes of the alternatives for the specialist soils and land capability aspects the following pertain:

- Site B comprises better than average arable land and although mining of coal has occurred on the west central portion of the site, a significant portion is still available for agricultural use. No additional mining is apparent, and a significantly large informal settlement is present in the north western sector
- Site C has significantly large areas of wet based soils and wetland status land, and although mining is prevalent to the north of the proposed site, there is evidence that active mining is planned and has been initiated across much of the site in question.
- Site F has been impacted by mining, and very little land remains that could be used for commercial agriculture. Significant portions of the site have already been rehabilitated, and that which has not been rehabilitated is highly disturbed and will need to be actively reinstated if closure is to be obtained. There are very few settlers on the land, either formal or informal, and although the site does boarder on the Kendal Town lands to the south west there is sufficient buffer area that could be used to mitigate the impact on people. The disturbed nature of Site F and the fact that a significant proportion of the site has had the soils removed and stockpiled already is noteworthy. We are of the opinion that it is environmentally responsible to use disturbed sites for the deposition of permanent waste dumps than using soils and land that has the potential to sustain a food supply for the country.
- Site H has been impacted by commercial farming for the most part with significant areas of well-established maize and annual crops planted to both dryland cultivation as well as centre pivot irrigation.
- There is no mining on the area of concern and only very limited habitation other than the farm homestead and a small number of farm employee dwellings. The disturbed nature of Site H by agriculture is only significant in that the eco system services and socio economic aspects will be impacted.
- The Agricultural Potential Study returned ratings for a significant proportion of the study area of "moderate to good", a rating conducive to moderate arable potential under good management conditions and additions of pertinent fertilisers and water.
- In addition, additional areas (???ha) of the site are considered moderate grazing potential in terms of the land capability, and moderate to poor arable potential sites on the ASR system of agricultural potential

  We are of the opinion that it is environmentally responsible to use disturbed sites for the deposition of permanent waste dumps than using soils and land that has the potential to sustain a food supply for the country. Site H should therefore not be considered as the primary candidate site for an ashing facility in terms of the soil and land capability assessment

Based on these findings, it is evident that Site "F" is considered to be the best candidate site for an Ash Storage Facility.

It is however the opinion of the lead consultant and authorities based on the overall weighting of specialist inputs that Site "H" is the optimum site and should be considered in terms of impact assessment.

Table 2.4 – Alternative Assessment Matrix

KENDAL 30 YEAR ASH DUMP - SITE SENSITIVITY ANAYSIS

Ash Storage Facility - Alternatives Analysis Matrix

Considerations				Alternative							
				Site Option B		Site Option C		Site Option F		Site Option H	
Account	Sub-account	Indicator	Indicator weighting	Score	Description	Score	Description	Score	Description	Score	Description
Aspects of Physical Environment	Present Land Use	Habitation & Existing Use	0	3	Limited habitation associated with existing mining venture and on north western boundary. 15% under existing mining activity.	3	Limited to no habitation, but significantly more mining than is suggested by the aerial photographs used. Potentially 50% of area is either mined out is in process of being mined.	2	Existing and ongoing mining - rehabilitation and some informal settlements on edge of Kendal Townlands Approx 70% area disturbed by mining (still to be rehabilitated in places).	4	Area under commercial farming, with limited subsistance farming, farm dwellings and no existing mining.
		Cultivation or Grazing Usage	0	6	Significant area of cultivated annual pastures and commercial cropping - estimated that >70 of area is utilised, but soils are generally of a grazing land rating and status.	5	Area not mined out or disturbed by mining is under cultivation if not too wetHigh % of Cultivation - > 95% under irrigation and/or cultivated lands	2	Natural veld grass and limited cultivation on small areas within mining boundary. Highly disturbed and not very productive. Some rehabiltated ground could be reinstated for grazing once mining is completed.	6	Majority of the site is cultivated to commercial production of maize. Natural veld grasses confined to wet areas (Pans) and stream environments.
		Subsistance usage	0	4	Limited usage, but area of more formalised settlement (water and electricity installed) has grown since aerial imagery was produced.	1	None	2	None	2	None
	Sub-account value		0	13		9		6		12	
	Soils	Presence of sensitive soils	0	4	Some indications of wet based or transitional zone soils - Sensitive and require managemnt inputs. Wet based soils associated with waterways and possible lithological change in central portion of site (dolerite?).	5	Limited but significant area of wet based and/or Transitional Zone soils associated with the Pan structures in the northern sector (mined out in most cases) and undisturbed areas of wetland status soils along river system in the south and east.	2	Limited wet based and transitional zone soils associated with the minor water way - only moderately sensitive. Appear to have been left out of mining operation. Affected by dirty water and dust, and significant portion of site underlain by gravel layer (Soft and/or hard plinthite).	6	Significant areas of wet based and transitional zone soils associated with the Pan and stream/water ways - sensitive to highly sensitive with areas of wetlands and lateritic/hard plinthic barrier to water infiltration.
		Soil Workability	0	3	Sandy loams to silty clay loams for the most part - moderately easily worked for all but the wet based soils (significant area of proposed site)	5	Friable sandy loams to sandy clay loams - Easily worked and stored for all but the wetland status and wet based soils.	2	Modertely shallow sandy loams and silty clay loams where soils stilll exist- Generally easily worked and stored.	4	Modertely deep to deep sandy loams and silty clay loams with significant areas of utilisable soil cover. Moderately easy to easily worked, stored and rehabilitated.
		Erosion Sensitivity	0	4	Moderate to shallow and flat gradients, moderate to low clay, and poor organic matter content - Moderate to high erosion if not protected, or if impacted by vegetation removal.	4	Flat to undulating terrain - moderate clay probably, but low organic carbon content to soils - Moderate to high erosion index if not protected.	4	Flat to undulating terrain, moderate to shallow profiles with moderate to good grazing potential. Unprotected soil are sensitive to erosion. Rehabilitated areas need to be vegetated as soon as possible after re-instatement	4	Flat to undulating terrain, moderate to deep soil profiles with moderate to good grazing potential. Unprotected soil are sensitive to erosion. Rehabilitated areas need to be vegetated as soon as possible after re-instatement
	Sub-account value		0	11		14		8		14	
	Land Capability	Arable Potential of Soils	0	2	Generally moderately deep to shallow soil depth with transitional zone soils associated with a gravel or ferricrete layer at base - Limited arible potential unless activily farmed and additives included in overall costs.	6	Generally moderate to deeper soils - Moderate to good arible potential if cultivated and additives considered. Significant areas of wet based soils that cannot/should not be grazed or cultivated.	3	Very limited arable potential - generally shallow with limited wet based soils associated with the water way. 70% area disturbed by previous or existing mining, some rehabilitatied areas - grazing potential	4	Limited arable potential - generally moderately deep but profiles but with wet base to soil profiles. Generally good grazing potential land
		Grazing Potential of Soils	0	3	Significant but small areas of moist grassmands associated with wet based soils and transition zone - difficult to work and considered sensitive -At best moderate grazing potential on areas outside of the valley bottoms - west and estern areas.	5	Limited natural grassland savanha, and significant wet based or transitional zone soils, generally better than average to good grazing potential	3	Moderate grazing potential for majority of area (rehabilitated and small areas of remaining undisturbed lands).	6	Moderate to good grazing potential for majority of area, albeit that the majority of the site has been planted to commercial crops.
		Conservation Potential of Soils	0	3	Limited wet based and transiton zone soils - Need to be conserved	2	Limited shallow soils or soils with sensitive nature that need to be conserved	2	Limited wet based transitional zone soils associated with the teriary drainage channels and water way.	3	Occurrence of significant area of wet based transitional zone soils associated with the tertiary drainage channels and water way.
	Sub-account value		0	8		13		8		13	
	Overall Value		0.0	32	2	36	3	22	1	39	4

Notes:
The table is a straight comparison of the four sites using a scale of 1 to 9, where 1 = Highly Suitable and 9 = Not Suitable.
Lowest score = Best site for Ash Dump.

3. ENVIRONMENTAL IMPACT ASSESSMENT - PHILOSOPHY

With the baseline for the alternative study in hand, and with the consensus for Site "H" having been tabled as the overall best candidate site, the development plan for Site H was tabled.

The impact assessment has been based on the actions and activities as described in the development plan entitled "**KENDAL 30 YEAR ASH DISPOSAL FACILITY – CONCEPTUAL ENGINEERING DESIGN and dated 08th December 2014".**

The baseline information forms the basis for the existing state of the environment for the study area, the relative sensitivities and areas of concern having been highlighted and used as the basis for the Impact Assessment, with the establishment of Site "H" as the preferred option. (Refer to Figure 5.1a – Soil Sensitivity Map).

This report has been compiled in line with the South African Integrated Environmental Management Information Series (DEAT 2002), a guideline to the Impact Assessment philosophy and Significance Rating System.

This system aims to identify and quantify the physical environmental and/or social aspects of the proposed activities inclusive of any alternatives, to assess how these aspects will affect the existing state, and link the aspects to variables that have been defined in terms of the baseline study.

In addition, the impact assessment has defined a maximum acceptable level of impact for each of the activities or variables, inclusive of any standards, limits and/or thresholds, and has assessed the impact in terms of the significance rating as defined by the lead consultants.

The environmental aspects are not least of all part of the information that is needed in this decision making, with an understanding of how the soils and land capability will be affected being just part of the overall sustainability equation that needs to be balanced.

The principle of "No Net Loss" has been considered the baseline principle that should be aimed for wherever possible. However, the development/construction and operation of a mega ash disposal facility and its support infrastructure (pipelines, power reticulation, access roads and stormwater control facilities) and the fact that the structure is a permanent feature will challenge this concept.

Based on the outcomes of the impact assessment, the site specific management planning and mitigation measures have been defined and detailed. These include defining what the mitigation will do to reduce the intensity and probability of the impact, specify a performance expectation for the mitigation proposed, and ensure that the prescriptive mitigation proposed is clear, site specific and practical.

In addition, and as part of the practical management plan, a monitoring system has been defined and any legal limits or provisions listed.

As part of understanding the variables and the maximum acceptable levels of impact that will be considered by the authorities, a summary of the national legislation that pertains to soils has been considered. These will aid in setting the permissible standards and limits that can be considered, albeit that there are no prescribed limits available.

The following section outlines a summary of the South African Environmental Legislation that needs to be considered for any new development with reference to management of soil:

- *The law on Conservation of Agricultural Resources (Act 43 of 1983) states that the degradation of the agricultural potential of soil is illegal.*
- *The Bill of Rights states that environmental rights exist primarily to ensure good health and wellbeing, and secondarily to protect the environment through reasonable legislation, ensuring the prevention of the degradation of resources.*
- *The Environmental right is furthered in the National Environmental Management Act (No. 107 of 1998), which prescribes three principles, namely the precautionary principle, the "polluter pays" principle and the preventive principle.*
- *It is stated in the above-mentioned Act that the individual/group responsible for the degradation/pollution of natural resources is required to rehabilitate the polluted source.*
- *Soils and land capability are protected under the National Environmental Management Act 107 of 1998, the Environmental Conservation Act 73 of 1989, the Minerals Act 50 of 1991 and the Conservation of Agricultural Resources Act 43 of 1983.*
- *The National Veld and Forest Fire Bill of 10 July 1998 and the Fertilizer, Farm Feeds, Agricultural Remedies and Stock Remedies Act 36 of 1947 can also be applicable in some cases.*
- *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 minimized and remedied.*
- *The Minerals Act of 1991 requires an EMPR, in which the soils and land capability be described.*
- *The Conservation of Agriculture Resources Act 43 of 1983 requires the protection of land against soil erosion and the prevention of water logging and salinization of soils by means of suitable soil conservation works to be constructed and maintained. The utilization of marshes, water sponges and water courses are also addressed*.

In addition to the South African legal compliance as listed, this proposed development has also been assessed in terms of the International Performance Standards as detailed by the International Finance Corporation.

The IFC has developed a series of Performance Standards to assist developers and potential clients in assessing the environmental and social risks associated with a project and assisting the client in identifying and defining roles and responsibilities regarding the management of risk.

Performance Standard 1 establishes the importance of:

- Integrated assessment to identify the social and environmental impacts, risks, and opportunities of projects;
- Effective community engagement through disclosure of project-related information and consultation with local communities on matters that directly affect them; and
- The client's management of social and environmental performance throughout the life of the project.

Performance Standards 2 through 8 establish requirements to avoid, reduce, mitigate or compensate for impacts on people and the environment, and to improve conditions where appropriate.

While all relevant social and environmental risks and potential impacts should be considered as part of the assessment, Performance Standards 2 through 8 describe potential social and environmental impacts that require particular attention in emerging markets.

Where social or environmental impacts are anticipated, the client is required to manage them through its Social and Environmental Management System consistent with Performance Standard 1.

Of importance to this report are:

- The requirements to collect adequate baseline data;
- The requirements of an impact/risk assessment;
- The requirements of a management program;
- The requirements of a monitoring program; and most importantly;
- To apply relevant standards (either host country or other).

With regard to the application of relevant standards (either host country or other) there are no specific guidelines relating to soils and land use/capability, either locally or within the World Bank's or IFC's suite of Environmental Health and Safety Guidelines. The World Bank's Mining and Milling, Underground guideline does state, however, that project sponsors are required to prepare and implement an erosion and sediment control plan. The plan should include measures appropriate to the situation to intercept, divert, or otherwise reduce the stormwater runoff from exposed soil surfaces, tailings dams, and waste rock dumps.

Project sponsors are encouraged to integrate vegetative and non-vegetative soil stabilization measures in the erosion control plan.

Sediment control structures (e.g., detention/retention basins) should be installed to treat surface runoff prior to discharge to surface water bodies. All erosion control and sediment containment facilities must receive proper maintenance during their design life. This will be included in the appropriate management plans when they are developed at a later stage in the project's life cycle.

The variation in soil structure, texture and clay content of the soils combined with the presence of a prominent ferricrete (evaporite) layer at the base of many of the soil profiles ("C" Horizon), all make for a complex of natural conditions that are going to be extremely difficult to replicate during the rehabilitation stage and at closure.

The potential and probable loss of soil water and the "perched" aquifer that is believed to occur as a result of the ferricrete inhibiting/barrier layer will need to be assessed and understood as a function of the ecological balance.

The low levels of organic carbon and relatively low nutrient stores noted for many of the soils will also require that a sound management plan is adopted based on the best impact assessment information.

The concept of "**utilisable soil**" storage will be tabled as a basic management tool, and a function of good environment practise.

Soils are considered sensitive and important to the ecological cycle while forming an integral part of the eco system services.

Erosion and compaction are two of the more sensitive aspects that need to be considered and which will occur to varying degrees and, although tempered by the relative flatness of the terrain, they will need a well formulated management plan and adequate engineering if they are exposed and disturbed.

In addition, the variable depth profiles of the materials mapped are of concern as the depths of utilisable soil that can be stripped and stored will make for challenging management if all of the utilisable soils are to be harvested (large volumes).

Soils are extremely important to the long term sustainability of any project and will need to be stripped during construction, stored and maintained during the operational stage, and reinstated at closure (rehabilitation and emplacement of stored soils).

The impact of development on the soils and the resultant change in the land capability will be varied due to the differences associated with the soil forming processes and the resultant variation in the soil physical and chemical composition. The materials range from well-developed in-situ derived sandy and silty loams associated with the sedimentary lithologies to clay rich and well-structured sandy clays and clay loams associated with the more basic intrusive lithological units. These are contrasted with more recent colluvial and alluvial derived materials that show less well defined pedogenisis and comprise a range of structure and texture.

These factors will be important in the environmental assessment and final management plan that is tabled, with the “separation” and management of the differing materials at the removal stage (construction) forming the basis for economically and sustainable rehabilitation at closure.

The moderately complex nature of the geology (physical and chemical) and geomorphology of the area and the semi-arid climate, all play a significant role in the soil forming process, and have a bearing on the sensitivity and/or vulnerability of the materials when being worked or disturbed.

These factors are important not only in planning the construction and operational activities, but will determine the success of the rehabilitation planning for the future.

4. ENVIRONMENTAL IMPACT ASSESSMENT METHODOLOGY

4.1 Impact Assessment Methodology

The impacts will be ranked according to the methodology described below. Where possible, mitigation measures will be provided to manage impacts. In order to ensure uniformity, a standard impact assessment methodology will be utilised so that a wide range of impacts can be compared with each other. The impact assessment methodology makes provision for the assessment of impacts against the following criteria:

- Significance;
- Spatial scale;
- Temporal scale;
- Probability; and
- Degree of certainty.

A combined quantitative and qualitative methodology was used to describe impacts for each of the aforementioned assessment criteria. A summary of each of the qualitative descriptors along with the equivalent quantitative rating scale for each of the aforementioned criteria is given in **Table 4-1**.

Table 4-1: Quantitative rating and equivalent descriptors for the impact assessment criteria

Rating	Significance	Extent Scale	Temporal Scale
1	VERY LOW	*Proposed site*	Incidental
2	LOW	*Study area*	Short-term
3	MODERATE	*Local*	Medium-term
4	HIGH	*Regional / Provincial*	Long-term
5	VERY HIGH	*Global / National*	Permanent

A more detailed description of each of the assessment criteria is given in the following sections.

Significance Assessment

Significance rating (importance) of the associated impacts embraces the notion of extent and magnitude, but does not always clearly define these since their importance in the rating scale is very relative. For example, the magnitude (i.e. the size) of area affected by atmospheric pollution may be extremely large (1 000 km^2) but the significance of this effect is dependent on the concentration or level of pollution. If the concentration is great, the significance of the impact would be HIGH or VERY HIGH, but if it is diluted it would be VERY LOW or LOW. Similarly, if 30 ha of a grassland type are destroyed the impact would be VERY HIGH if only 100 ha of that grassland type were known. The impact would be VERY LOW if the grassland type was common. A more detailed description of the impact significance rating scale is given in Table 4.2 below.

Table 4-2: Description of the significance rating scale

Rating		Description
5	Very high	Of the highest order possible within the bounds of impacts which could occur. In the case of adverse impacts: there is no possible mitigation and/or remedial activity which could offset the impact. In the case of beneficial impacts, there is no real alternative to achieving this benefit.
4	High	Impact is of substantial order within the bounds of impacts, which could occur. In the case of adverse impacts: mitigation and/or remedial activity is feasible but difficult, expensive, time-consuming or some combination of these. In the case of beneficial impacts, other means of achieving this benefit are feasible but they are more difficult, expensive, time-consuming or some combination of these.
3	Moderate	Impact is real but not substantial in relation to other impacts, which might take effect within the bounds of those which could occur. In the case of adverse impacts: mitigation and/or remedial activity are both feasible and fairly easily possible. In the case of beneficial impacts: other means of achieving this benefit are about equal in time, cost, effort, etc.
2	Low	Impact is of a low order and therefore likely to have little real effect. In the case of adverse impacts: mitigation and/or remedial activity is either easily achieved or little will be required, or both. In the case of beneficial impacts, alternative means for achieving this benefit are likely to be easier, cheaper, more effective, less time consuming, or some combination of these.
1	Very low	Impact is negligible within the bounds of impacts which could occur. In the case of adverse impacts, almost no mitigation and/or remedial activity are needed, and any minor steps which might be needed are easy, cheap, and simple. In the case of beneficial impacts, alternative means are almost all likely to be better, in one or a number of ways, than this means of achieving the benefit. Three additional categories must also be used where relevant. They are in addition to the category represented on the scale, and if used, will replace the scale.
0	No impact	There is no impact at all - not even a very low impact on a party or system.

Spatial Scale

The spatial scale refers to the extent of the impact i.e. will the impact be felt at the local, regional, or global scale. The spatial assessment scale is described in more detail in **Table 4-3.**

Table 4-3: Description of the significance rating scale

Rating		Description
5	Global/National	The maximum extent of any impact.
4	Regional/Provincial	The spatial scale is moderate within the bounds of impacts possible, and will be felt at a regional scale (District Municipality to Provincial Level).
3	Local	The impact will affect an area up to 10 km from the proposed site.
2	Study Site	The impact will affect an area not exceeding the Eskom property.
1	Proposed site	The impact will affect an area no bigger than the ash disposal site.

Duration Scale

In order to accurately describe the impact, it is necessary to understand the duration and persistence of an impact in the environment. The temporal scale is rated according to criteria set out in **Table 4-4**.

Table 4-4: Description of the temporal rating scale

Rating		Description
1	Incidental	The impact will be limited to isolated incidences that are expected to occur very sporadically.
2	Short-term	The environmental impact identified will operate for the duration of the construction phase or a period of less than 5 years, whichever is the greater.
3	Medium term	The environmental impact identified will operate for the duration of life of facility.
4	Long term	The environmental impact identified will operate beyond the life of operation.
5	Permanent	The environmental impact will be permanent.

Degree of Probability

Probability or likelihood of an impact occurring will be described as shown in **Table 4-5** below.

Table 4-5: Description of the degree of probability of an impact occurring

Rating	Description
1	Practically impossible
2	Unlikely
3	Could happen
4	Very Likely
5	It's going to happen / has occurred

Degree of Certainty

As with all studies it is not possible to be 100% certain of all facts, and for this reason a standard "degree of certainty" scale is used as discussed in Table 4.6. The level of detail for specialist studies is determined according to the degree of certainty required for decision-making. The impacts are discussed in terms of affected parties or environmental components.

Table 4-6: Description of the degree of certainty rating scale

Rating	Description
Definite	More than 90% sure of a particular fact.
Probable	Between 70 and 90% sure of a particular fact, or of the likelihood of that impact occurring.
Possible	Between 40 and 70% sure of a particular fact or of the likelihood of an impact occurring.
Unsure	Less than 40% sure of a particular fact or the likelihood of an impact occurring.
Can't know	The consultant believes an assessment is not possible even with additional research.
Don't know	The consultant cannot, or is unwilling, to make an assessment given available information.

Quantitative Description of Impacts

To allow for impacts to be described in a quantitative manner in addition to the qualitative description given above, a rating scale of between 1 and 5 was used for each of the assessment criteria. Thus the total value of the impact is described as the function of significance, spatial and temporal scale as described below:

$$Impact\ Risk = \frac{(Significance + Spatial + Temporal)}{3} \times \frac{Probability}{5}$$

An example of how this rating scale is applied is shown below:

Table 4-7: Example of Rating Scale

Impact	Significance	Spatial Scale	Temporal Scale	Probability	Rating
	LOW	*Local*	Medium-term	*Could Happen*	
Impact to air	**2**	***3***	**3**	**3**	**1.6**

Note: The significance, spatial and temporal scales are added to give a total of 8, that is divided by 3 to give a criteria rating of 2.67. The probability (3) is divided by 5 to give a probability rating of 0.6. The criteria rating of 2.67 is then multiplied by the probability rating (0.6) to give the final rating of 1,6.

The impact risk is classified according to five classes as described in the **Table 4-8** below.

Table 4-8: Impact Risk Classes

Rating	Impact Class	Description
0.1 – 1.0	**1**	**Very Low**
1.1 – 2.0	**2**	**Low**
2.1 – 3.0	**3**	**Moderate**
3.1 – 4.0	**4**	**High**
4.1 – 5.0	**5**	**Very High**

Therefore, with reference to the example used for air quality above, an impact rating of 1.6 will fall in the Impact Class 2, which will be considered to be a low impact.

Cumulative Impacts

It is a requirement that the impact assessments take cognisance of cumulative impacts. In fulfilment of this requirement the impact assessment will take cognisance of any existing impact sustained by the operations, any mitigation measures already in place, any additional impact to environment through continued and proposed future activities, and the residual impact after mitigation measures.

It is important to note that cumulative impacts at the national or provincial level will not be considered in this assessment, as the total quantification of external companies on resources is not possible at the project level due to the lack of information and research documenting the effects of existing activities. Such cumulative impacts that may occur across industry boundaries can also only be effectively addressed at Provincial and National Government levels.

Notation of Impacts

In order to make the report easier to read the following notation format is used to highlight the various components of the assessment:

- Significance or magnitude- IN CAPITALS
- Temporal Scale – in <u>underline</u>
- Probability – in <u>*italics and underlined*</u>
- Degree of certainty - in **bold**
- Spatial Extent Scale – in *italics*

Of consequence to the soils and land capability of the areas to be affected are the changes that the activities and related support aspects being planned will have on the existing physical and socio economic state of the environment.

5. ENVIRONMENTAL IMPACT ASSESSMENT/STATEMENT

The EIA methodology and philosophy is covered in the preceding sections, and with the alternatives assessment concluded a significant amount of baseline information is available along with an understanding of the activities and how they will impact the soils and land capability during the construction and operation of the proposed ash conveyencing and disposal.

The engineering design and project description have been used as the basis for the EIA and associated EMP (Refer to Figure 5.1a – Engineering Design – Site "H"), while the outcomes of the baseline studies (soils, land capability and Agricultural Potential Study) and sensitivity analysis is detailed in Figure 5.1b attached

Based on these factors and outcomes, an assessment (EIA) of the environmental impacts that these activities might produce has been carried out and measured against the existing environmental state for Site H using the significance rating supplied.

This section assesses and measures/quantifies where possible the environmental aspects of the **activities** in terms of how they will affect the **existing state/status quo**, and details where possible/available the maximum acceptable level of impact for each of the variables listed.

Based on these findings, the **significance/impact risk** is rated in terms of its unmanaged and managed state, with the management recommendations forming the basis of the Environmental Management Plan (Chapter 6).

Of significance to the proposed development and the sustainability of any project are the sensitivities of many of the soils (Refer to Figure 5.1b).

The sensitivities considered important when assessing the soil environment include, soil depth, soil structure and texture (clay content etc.), the chemical composition (organic carbon etc.) and the soils erodibility and compactability. These variables are often manifest by particular soil features or resultant land forms and variations in the overall geomorphology, and are in almost all cases associated with other ecological aspects or considerations of biodiversity importance. The eco system services have also been considered as part of the Agricultural Potential Study.

At the extreme of sensitivity or vulnerability are the wetlands and wet based soils. In terms of the wetland delineation guidelines and the legal status of wetlands the highly sensitive areas need to be considered carefully if they are within the area of proposed impact.

There are no off-site activities included in this Environmental Impact Assessment, while the alternatives were considered. The assessment is confined to the project footprint (Site "H") and its immediate surroundings, and as such the "spatial extent is regarded as "Site Only" or at worst "Localised" depending on how far the effects of erosion are predicted to extend.

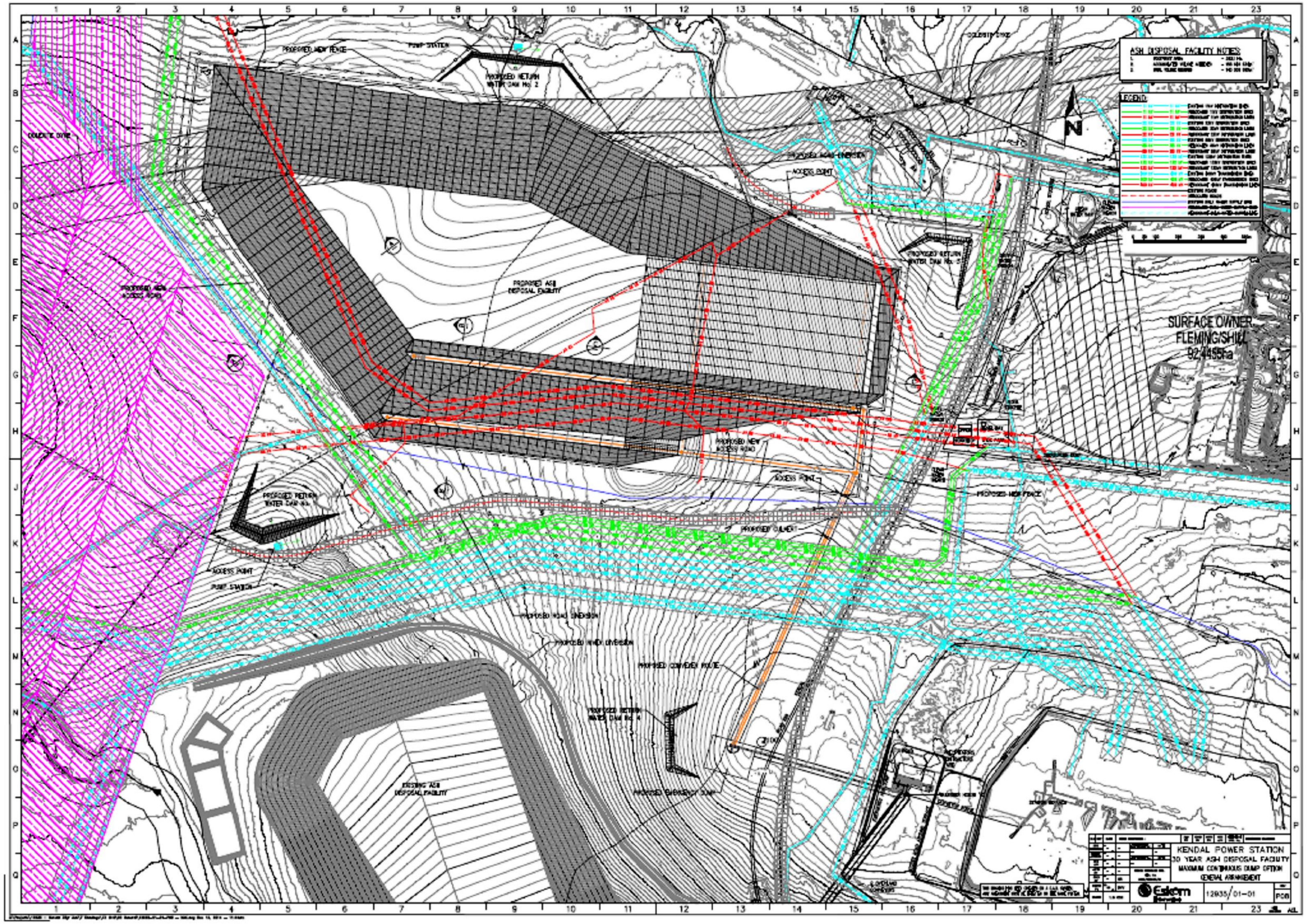

Figure 5.1a – Engineering Design – Site "H"

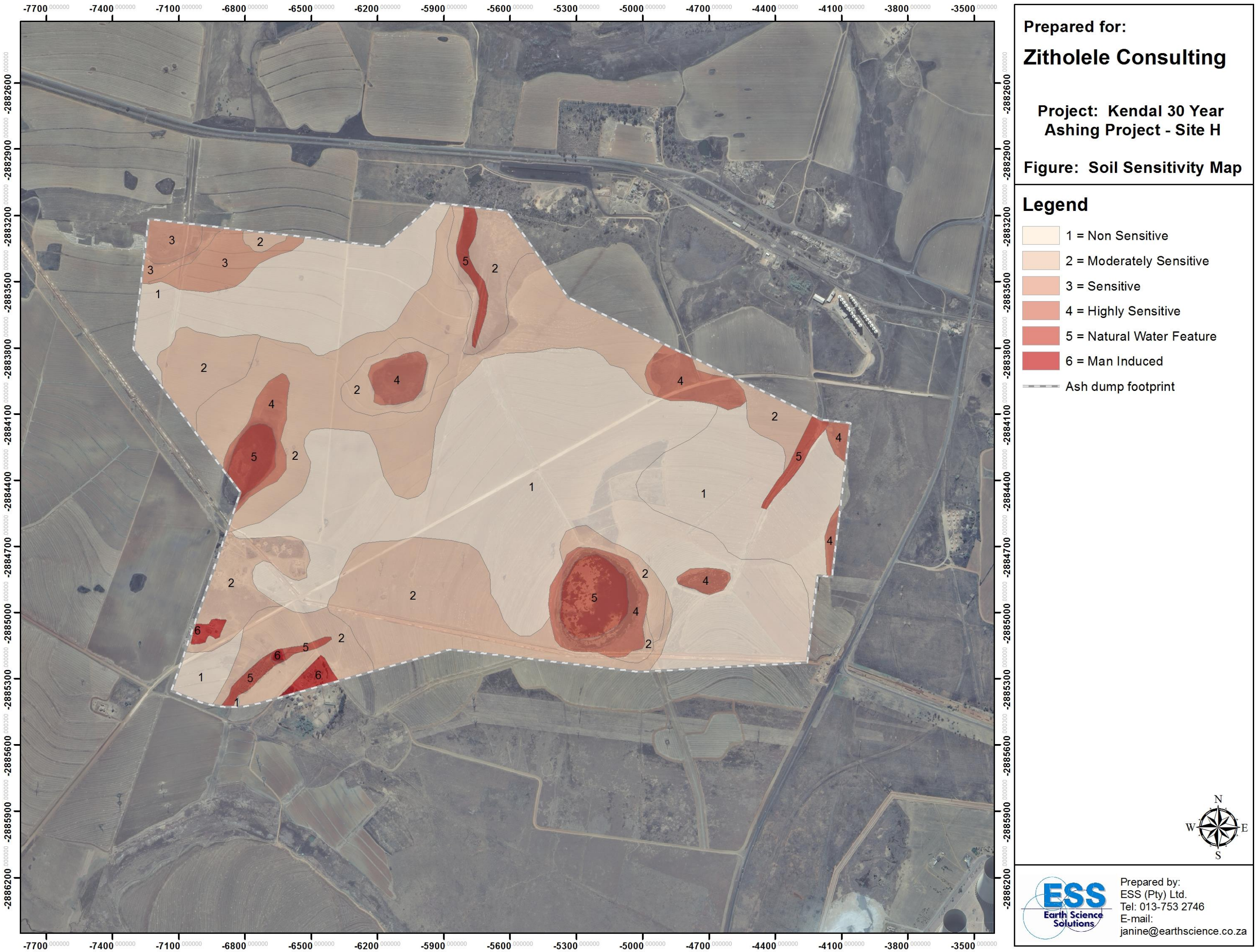

Figure 5.2 – Soil Sensitivity Map – Site H

The infrastructure planned for the facility will include (Refer to Design Reports) some large and heavy structures and relatively deep excavations (return water dams, ash facility liner and pump installations). These will entail the removal of significant quantities of soil, and possibly the complete removal of soil and soft overburden in places were the foundations for the larger structures (dams) are to be excavated.

The conveyer route and maintenance/access roadways will required less engineering as the size and weight of implements and machinery will be relatively much smaller/less, albeit that they will still require strong foundations with well-engineered sub-base for all plinth footings (conveyer and all above ground piping and stream crossings). These soils will however all be sterilized and lost from the system for the life of the operation and possibly beyond in the case of the permanent facility (Ash Disposal Facility).

A number of site specific baseline (existing environment) conditions are of special significance and need mention here if the relative impacts of the activities being planned are to be understood.

Of significance are:

- The underlying ferricrete layer (inhibiting layer), and its function as a barrier to soil water loss down the profile. This will in almost all cases [deep foundations or facilities (dams etc.)] be destroyed and possibly removed from the system where it exists;
- All/any pan structures that classify as wetlands are considered to be ecologically highly sensitive and important;
- The significant area of wet based soil that is being considered as part of the footprint to the developments including the PCDs.;
- The relatively low clay content of all but the more basic derived soils and the low organic carbon render most of the soils susceptible to erosion, while,
- The wet based soils and some of the more basic derived soils will compact if subjected to heavy loads.

These conditions will have a bearing on the ratings being assigned to the overall impact statement as loss of these features will have a definite localised negative impact that is of significance to the ecological functionality of the area. These variables have a bearing on the management recommendations made.

In addition to the baseline soil and land capability for the proposed site is the pre-development conditions or status quo for the area of concern. For the most part the site comprises commercial farmlands that are being cultivated to annual crops (cereals, potatoes and soya beans) or pastures for commercial livestock farming.

The status quo constitutes a brownfields environment, with significant negative impacts associated with the farming ventures. These have been assessed in some detail, albeit that little information is available of the original unaffected environment. The impacts will be associated with:

- The changes to the soil physical and chemical composition, the potential contamination (over supply and thus contamination by fertilisers that cannot be taken up by the plants and which will leach into the soil water and ultimately the groundwater environment),
- Erosion and loss of soils from unprotected cultivation and the effects of wind and water and the impacts of the added sedimentary load on the streams and rivers/dams of the area,
- Compaction by farm vehicles on unprotected lands and
- The contamination of the soils from hydrocarbon spills from farm implements.

These impacts have been taken into account when assessment of the proposed development is considered in its unmanaged and unmitigated state.

5.1 Planned Ash Disposal Facility Activities

The key activities planned for the development include:

- A fixed conveyor will be constructed from the existing Emergency Disposal Facility (E-Disposal) at the power station and will cross under Road 545 to the other side of the road were a proposed new Emergency Disposal Facility (E-Disposal Facility) will be constructed;
- Fixed conveyors will extend from the proposed new E-Disposal Facility towards the new proposed ADF on to which extendable and then shift-able conveyors will be fixed in order to dispose ash on the footprint of the proposed new ADF;
- Ashing on the proposed new ADF footprint will commence from the eastern side of the footprint towards the western end of the footprint;
- A 1:15 sloped ramp will be constructed on the eastern side of the proposed new ADF and will reach the maximum height of the proposed new ADF, 75 metres;
- Several power lines will be diverted:
    - ✓ 400 kV: 2 No. off
    - ✓ 88 kV: 2 No. off
    - ✓ 22 kV: 2 No. off
    - ✓ 132 kV: 2 No. off
- The proposed new ADF is tapered on the south western corner due to parcels of land that have mining rights attached to them, situated on the western side of the site, and the need to avoid utilising these parcels of land;
- The proposed new ADF will have a ring access road constructed around its perimeter together with stormwater canals intercepting impacted runoff and directing to a pollution control dam;
- The Kusile Bulk Water line **will not** be relocated (for Scenario 1 only);
- Four (4) proposed new dams are to be constructed. Two (2) pollution control dams (PCD) at the proposed new ADF, one (1) PCD at the proposed new E-Disposal Facility and one (1) clean water dam. Pump stations will be constructed at each of the dams;
- Road D1390 which runs through the proposed new ADF footprint will need to be diverted. The new diverted alignment of the road is on the southern side of the proposed new ADF and intersects with the access road leading to the Kendal Power Station main entrance.;
- The new diverted Road D1390 will have a 40 metre road reserve;
- There will be three (3) access points to the proposed new ADF;
- For both the Maximum and Minimum Continuous Disposal Facility Options, a distance of 500 metres has been achieved between the existing silos, on the north eastern side of the proposed new ADF, and the perimeter of the proposed ADF;
- The liner construction will be staged in Three (3) year stages. At any given point there will be 1 – 2 years of available footprint of constructed liner;
- The starter ramp wall for the proposed new ADF will be constructed with bulldozers. The rest of the proposed new ADF will be constructed with the conveyor-stacker system;

With an understanding of the activities that will occur as part of the proposed project, the construction and operational activities and support facilities and its associated infrastructure (conveyencing of the waste materials to the ash disposal site, and the management and reticulation of the dirty water), it is concluded that the **major** concerns and probable impacts that could affect the soils and associated land capability are associated with:

- The loss of the soil resource due the **change in land use** and the removal of the resource from the existing system (Sterilisation). These conditions are generally associated with the construction of the facility and its support infrastructure. The proposed waste depositional activities will potentially result in the complete loss of the soil resource for the life of the project. In the case of the ADF footprint this will be permanent, while some, or all of the support activities will be removed and the footprint rehabilitated. The ADF is planned to be capped and top dressed with soil.
- The on-going management of waste as the impact could potentially sterilise the soils permanently, if not removed/striped, stored and well managed;
- The loss of the soil resource due to **erosion** (wind and water) of unprotected materials due to the removal of vegetative cover and/or topsoil;
- The loss of the utilisation potential of the soil and land capability due to **compaction** of areas adjacent to the constructed facilities by vehicle and construction activities;
- Loss of the resource due to **removal** of materials for use in other activities (dam wall construction, development of berms and the storage of the soils in stockpiles);
- The **contamination** of the resource due to spillage of waste materials and the possibility of spillage of reagents that are transported to the site or used for the maintenance and operation of the infrastructure (conveyers etc.);
- The **contamination** of stored or in-situ materials due to dust or dirty water from the project area and transport routes;
- The loss of the soil utilisation potential due to the **disturbance** of the soils and potential loss of nutrient stores through leaching and de-nitrification of the stored or disturbed materials.

5.2 Impact Assessment

5.2.1 Construction Phase

Issue - Loss of utilisable resource (sterilization and erosion), compaction and contamination or salinization.

The construction phase will require:

- The stripping of all utilisable soil (Top 250mm to 700mm depending on activity);
- The preparation (levelling and compaction) of lay-down areas, foundations and pad footprint areas for stockpiling of utilisable soil removed from the footprint to the ADF, Pollution Control Dams (PCD) and Soil Stockpiles (SS),
- The stormwater management system (Dams, Water Reservoir etc.), and the foundations for the Site Offices and Site Workshops and all related support infrastructure;
- The clearing, stripping and stockpiling from the construction of all access and Conveyencing and Haulage Ways, Electrical Servitudes and Water Reticulation (pipelines and overhead power lines);
- The use of heavy machinery over unprotected soils;
- The creation of dust and loss of materials to wind and water erosion, and

- The possible contamination of the soils by dirty water, chemicals and hydrocarbons spills (dust and dirty water runoff);

Impact Risk

The loss of the utilisation of the soil resource will negatively impact the land use practice of low to moderate intensity livestock grazing and commercial cultivation of cereal crops (major land use activities) being undertaken on the dryland soils at present. These activities are perceived to be of great economic benefit to the local economy and land owners and contribute to the ecosystem services.

The construction for the Ash Disposal Facility and its support activities will, if un-managed and without mitigation have a **definite,** MODERATE to HIGH negative significance, that will affect the *development site and its immediate* surroundings for the medium to long term (life of the project and possibly beyond), and it is *going to occur*.

The proposed activities will, during construction result in:

- The loss of the soil materials, and as a result the use of the resource with the associated negative effects on the eco system services;
- Have the potential for contamination (hydrocarbon and reagent chemical spills, raw materials and spillage of coal, etc.), compaction of working/laydown areas and storage facility footprint and the potential for erosion (wind and water – dust and suspended solids) over unprotected/disturbed areas;
- Have a moderate to high negative intensity potential ranking based on the confined (limited to footprint of impact) nature/design of the facility and associated infrastructure;
- An impact that will continue throughout the construction phase and into the operational phase;
- Will be permanent but reversible (can be broken down and rehabilitated) for all but the actual depositional facility, and
- Is confined to the site only - localised.

However, with management, the loss, degree of contamination, compaction and erosion of the resource can be mitigated and reduced to a level that is more acceptable.

The reduction in the risk rating of the impact can be achieved by:

- Limiting the area of impact to as small a footprint as possible, inclusive of the resource (soils) stockpiles and the length of servitudes, access and haulage ways and conveyencing systems wherever possible;
- Construction of the facility and associated infrastructure over the less sensitive soil groups (reduce impact over wetlands and soils sensitive to erosion and/or compaction);
- An awareness of the length of time that the resource (soil) will need to be stored and managed;
- The development and inclusion of soil management as part of the general housekeeping operations, and the independent auditing of the management;
- Concurrent rehabilitation of all affected sites that are not required for the operation;
- The rehabilitation of temporary structures and footprint areas used during the feasibility investigation (geotechnical pits, trenching etc.) and the construction phase;

- Effective soil stripping during the less windy months when the soils are less susceptible to erosion;
- Separation of the utilisable soils and wet base materials (inclusive of any ferricrete) from each other and from the soft overburden;
- Effective cladding of the berms and soil stockpiles/heaps with vegetation or large rock fragments, and the minimising of the height of storage facilities to 15m and soil berms to 1,5m wherever possible;
- Restriction of vehicle movement over unprotected or sensitive areas, this will reduce compaction;
- Soil amelioration (cultivation) to enhance the oxygenation and growing capability (germination) of natural regeneration and/or seed within the stockpiled soils (maintain the soils viability during storage) and areas of concurrent rehabilitation.

It is noted within the industry, that failure to manage the impacts on this important resource (soil) will result in the total loss of the resource, with a resultant much higher significance rating.

Residual Impact

The above management procedures will **probably** reduce the negative significance rating and resultant risk impact to a MODERATE LOW rating that will be confined to the *development site and its immediate (500m) surroundings* in the medium term. Based on the historical actions of the proponent these actions are *very likely to occur.*

Table 5.2.1 - Construction Phase Risk Impact

PRE-CONSTRUCTION & CONSTRUCTION PHASE									
Activity	**Description of Impact**	**Impact type**	**Spatial Scale**	**Duration**	**Significance**	**Probability**	**Rating**	**Mitigation Measures**	**Interpretation**
Exploration and Geotechnical,	Loss of soil resource	Existing	1	2	2	5	1.7 - LOW	Removal of all structures, backfilling of sumps and revegetation of footprint of disturbance and tracks if needed	The land use in the area (agriculture) has both erosion and compaction associated with it, resulting in dust and sedimentation on streams and rivers.
		Cumulative	1	2	1	5	1.3 - LOW		The land clearing for exploration drilling and pitting will have only minor imacts and will not contribute significantly to the risk rating
		Residual	1	1	1	4	0.8 - VERY LOW		The impact can be mitiagted to a very low risk rating by applying mitigation measures
Environmental Studies and Design	Loss of soil resource	Existing	1	2	2	5	1.7 - LOW	Backfilling of any soil pits and rehabilitation of any tracks . Revegetation of soil pit footprint if necessary.	The land use in the area (agriculture) has both erosion and compaction associated with it, resulting in dust and sedimentation on streams and rivers.
		Cumulative	1	2	1	5	1.3 - LOW		The land clearing for exploration drilling and pitting will have only minor imacts and will not contribute significantly to the risk rating
		Residual	1	1	1	4	0.8 - VERY LOW		The impact can be mitiagted to a very low risk rating by applying mitigation measures
Clearing of footprint for access onto site, construction of laydown areas for soil stockpile and soft overburden from footprint to dam excavations (RWD) and ADF. Clearing for the erection of security fencing and clearing and construction of support infrastructure (administrative buildings, satallite workshop etc.) to the ADF.	Loss of soil utilisation potential for the project footprint	Existing	3	3	4	5	3.3 - HIGH	Removeal of all utilisable soil and storage of the same. Protect from impacts of erosion, compaction and contamination. Vegetate and/or cover with rock rap.	The commercial use of the land in the study area for food production will be perminantly lost from the ADF footprint
		Cumulative	3	3	4	5	3.3 - HIGH		Land clearing will imact significantly on soil erosion and compaction with a high risk of salinisation, sterilisation and contamination while being worked on.
		Residual	2	3	3	4	2.1 - MOD		Well managed stockpiles of soil and soft overburden resource will assist rehabilitation and final covering of ADF.
	Loss of vegetative cover and topsoil protection - possible erosion, the perminant loss of resource downslope and the impact of sedimentary load on receiving systems (streams, rivers pan etc.)	Existing	2	3	3	4	2.1 - MOD	Minimisation of footprint of impact, use of high floatation tires on all construction vehicles, removal and storage of utilisable soil and the re-vegetation and/or rock cover to all stored materials. Concurent rehabilitation where possible. Use of vetiver grass as erosion prevention ahead of clearing where erosion is a considered risk	The commercial use of the land in the study area for food production will be perminantly lost from the ADF footprint
		Cumulative	2	3	3	4	2.1 - MOD		Land clearing will imact significantly on soil erosion and compaction with a high risk of salinisation, sterilisation and contamination while being worked on.
		Residual	2	3	2	4	1.9 - LOW		Well managed stockpiles of soil and soft overburden resource will assist rehabilitation and final covering of ADF.
	Loss of soil resource and utilisation potential due to contamination by reagents and hydrocarbons spills and/or dirty water	Existing	2	3	3	4	2.1 - MOD	Restriction/minimisation of movement and servicing of vehicles, spillage from haulage systems and vehicles and the bunding of all services areas.	Impact from farming activities and use of heavy mechinary over unprotected soils will be negative and moderate.
		Cumulative	2	3	3	4	2.1 - MOD		Mining and the utilisation of heavy mechanery on unprotected soils will result in loss of resource and potential increase in sedimentation to receiving bodies, while the use of dirty water for dust suppression and the spillage of raw materials (ash) and hydrocarbons from vehicles will negativily influence the soils and associated land capability.
		Residual	2	3	2	4	1.9 - LOW		Well managed vehicle fleets and the control of and management of dirty water movement and raw material/waste spillage will reduce the overall impact
	Loss of resource and its utilisation potential due to compaction over unprotected ground/soil.	Existing	2	3	3	4	2.1 - MOD	Minimise the footprint of impact, restrict vehicle movement to areas of need, remove utisable soil to recommended depth, stockpile and then construct facilities. Rehabilitate areas once usefulness is completed.	Impact from farming activities and use of heavy mechinary over unprotected soils will be negative and moderate.
		Cumulative	2	3	3	4	2.1 - MOD		Mining and the utilisation of heavy mechanery on unprotected soils will result in loss of resource due to compaction.
		Residual	2	3	2	4	1.9 - LOW		Well managed mining plan the control of vehicle movements to specific pathways (access routes and haulage ways) will reduce the overall impact.
	Loss of soil and land capability due to reduction in nutrient status - de-nutrification and leaching due to stripping and stockpiling of resource	Existing	2	3	3	5	2.7 - MOD	Strip soils with vegetative cover in tacked, stockpile utilisable soils seperately from subsoils and soft overburden, restrict stockpiles and berms to less than 1,5m high for utilisable soil and 15m for the soft overburden, vegetate stores of soil and overburden and manage ingress of dirty water and erosion.	Soil nutrient status is ambient and of a naturally poor status due to natural chemistry of sediments from which soils are formed. Land capability is at best low intensity grazing land.
		Cumulative	2	3	3	5	2.7 - MOD		Stripping and stockpiling of soils will result in additional loss of nutrient status, albeit that the inclusion of vegetative matter will assist in retention of seed pool.
		Residual	2	3	2	4	1.9 - LOW		Well managed and well protected soil stockpiles will reduce the de-nitrification and loss of nutrient stores from the stockpiles

5.2.2 Operational Phase

Issue ***Loss of utilisable resource (Sterilization and erosion), compaction, de-nutrification and contamination or salinization.***

The operation of the Ash Disposal Facility development (deposition of ash, management of water and associated activities) will see the impact of the transportation of materials into and out of the waste site (ash and water in, water out), the potential for spillage and contamination of the in-situ and stockpiled materials, contamination due to dirty water run-off and/or contaminated dust deposition/dispersion, the de-nutrification of the stockpiled soils due to excessive through flow and the leaching out of nutrients and metals due to rain water on unconsolidated and poorly protected soils, and, the potential for compaction of the in-situ materials by uncontrolled vehicle movement and the loss to the environment (down-wind and downstream) of soil by wind and water erosion over un-protected ground.

In summary, the operation will potentially result in:

- The sterilisation of the soil resource on which the facilities are constructed. This will be an on-going loss for the duration of the operation and beyond;
- The creation of dust and the possible loss (erosion) of utilisable soil down-wind and/or downstream, and the potential for contamination of the soils from dust fallout and overland flow of dirty water;
- The compaction of the in-situ and stored soils and the potential loss of utilisable materials from the system;
- The contamination of the soils by dirty water run-off and or spillage of hydrocarbons from vehicle and machinery or from dust and emissions from the process;
- Contamination of soils by use of dirty water for road wetting (dust suppression) and irrigation of the stockpile vegetation;
- Potential contamination of soils by chemical spills of reagents being transported to site;
- Sterilisation and loss of soil nutrient pool, organic carbon stores and fertility of stored soils;
- Impact on soil structure and soil water balance.

Un-managed soil stockpiles and soil that is left uncovered/unprotected will be lost to wind and water erosion, will lose the all-important, albeit moderately poor nutrient content and organic carbon stores (fertility), and will be prone to compaction.

A positive impact will be the rehabilitation of the temporary infrastructure used during the start-up and construction phase.

<u>*Impact Significance*</u>

In the un-managed scenario these activities will **probably** result in a MODERATE to HIGH negative significance that will affect the *development footprint and adjacent* sites for the <u>medium to long term</u>. These effects are <u>*very*</u> likely to occur.

It is inevitable that some of the soils will be lost during the operational phase if they are not well managed and a mitigation plan is not made part of the general management schedule.

The impacts on the soils during the operational phase (stockpiled, peripheral soils and downstream (wind and water) materials) may be mitigated with well initiated management procedures.

These should include:

- Minimisation of the area that can potentially be impacted (eroded, compacted, sterilised or de-nutrified);
- Timeous replacement of the soils so as to minimise/reduce the area of affect and disturbance;
- Effective soil cover and adequate protection from wind (dust) and dirty water contamination – vegetate and/or rock cladding;
- Regular servicing of all vehicles in well-constructed and bunded areas;
- Regular cleaning and maintenance of all haulage ways, conveyencing routes and service ways, drains and storm water control facilities;
- Containment and management of spillage;
- Soil replacement and the preparation of a seed bed to facilitate and accelerate the re-vegetation program and to limit potential erosion on all areas that become available for rehabilitation (temporary servitudes), and
- Soil amelioration (rehabilitated and stockpiled) to enhance the growth capability of the soils and sustain the soils ability to retain oxygen and nutrients, thus sustaining vegetative material during the storage stage.

It will be necessary as part of the development plan to maintain the integrity of the stored soils so that they are available for rehabilitation at decommissioning and closure. If the soil quantities and qualities (utilisable soils) are managed well throughout the operational phase, rehabilitation costs will be reduced and natural attenuation will more easily and readily take effect. This will result in a more sustainable "End Land Use" being achieved.

Residual Impact

In the *long term* (Life of the operation and beyond) and if implemented correctly, the above mitigation measures will **probably** reduce the negative impact on the utilisable soil reserves (erosion, contamination, sterilization) to a significance rating of MODERATE LOW in the medium term, and is *very likely* to occur.

However, if the soils are not retained/stored and managed, and a workable management plan is not implemented the residual impact will definitely incur additional costs and result in the impacting of secondary areas (Borrow Pits etc.) in order to obtain cover materials etc.

Table 5.2.2 Operational Phase – Impact Significance

OPERATIONAL PHASE									
Activity	**Description of Impact**	**Impact type**	**Spatial Scale**	**Duration**	**Significance**	**Probability**	**Rating**	**Mitigation Measures**	**Interpretation**
Primarily storage and management of soil resource during the operation of the ADF for thr life of the project.	Continued loss of soil resource and utilisation potential over infrastructural sites and operational areas	Existing	3	3	4	5	3.3 - HIGH	Restrict area of impact to as small an area as practical and manage stockpiles for erosion by wind and water.	Unprotected soils and material stockpiles will be lost to wind and water erosion
		Cumulative	2	3	4	4	2.4 - MOD		Little or no cumulative effects will be imparted to the soils or affect the land capability during the operational phase.
		Residual	2	3	2	4	1.9 - LOW		Well protected soil stockpiles and in-situ materials will be more easily retained and available for rehabilitation at closure
	Loss of resource due to unprotected overland flow of water (suspended solids) and erosion of soil due to wind - potential off site dust issues	Existing	3	4	3	5	3.3 - HIGH	Manage stockplies and berms. Control vegetative cover and ingress of dirty water. Maintain stormwater control system and erosion due to unprotected soil cover.	Unprotected soils and material stockpiles will be lost to wind and water erosion
		Cumulative	2	3	4	4	2.4 - MOD		Little or no cumulative effects will be imparted to the soils or affect the land capability during the operational phase.
		Residual	2	3	2	4	1.9 - LOW		Well protected soil stockpiles and in-situ materials will be more easily retained and available for rehabilitation at closure
	Continued loss of soil utilisation due to contamination from spillage of waste, reagents and hydrocarbons from vehicles and mechanised infrastructure and from storage facilities (soil stockpiles).	Existing	3	3	3	5	3 - MOD	On-going management and control of vehicle maintenance, movements and cover to loads of raw materials. Spillage from haulage ways and vehicles to be claened regularly and placed back into the processing system.	Unmanaged and uncontrolled spillage and lack of vehicle maintenance will negativily impact of soils, while dirty water resulting from spillage of raw materials and/or hydrocarbons will impact the stockpiles and soil storage facilities negativily.
		Cumulative	2	3	2	4	1.9 - LOW		Little or no cumulative effects will be imparted to the soils or affect the land capability during the operational phase.
		Residual	2	3	2	4	1.9 - LOW		Well managed and controlled vehicle maintenance and spillage control from haulage vehicles or conveyer lines will assist in controlling the negative impacts of contamination of the soils.
	Loss of soil utilisation potential due to operation of conveyers and site mechaniery, stormwater controls (pumps etc.) and the loss of nutrient stores and organic carbon from unprotected stockpiles and in-situ contamination on sites.	Existing	3	3	3	5	3 - MOD	Maintenance of cover (vegetative or rock) to stockpiles and berm storage piles, cultivation and enplacement of stormwater and erosion control features and restriction of ingress of dirty water.	Unmanaged and uncontrolled spillage and lack of vehicle maintenance will negativily impact of soils, while dirty water resulting from spillage of raw materials and/or hydrocarbons will impact the stockpiles and soil storage facilities negativily and render the soils un-usable for rehabilitation and closure.
		Cumulative	2	3	2	4	1.9 - LOW		Little or no cumulative effects will be imparted to the soils or affect the land capability during the operational phase.
		Residual	2	3	2	4	1.9 - LOW		Well managed and controlled vehicle maintenance and spillage control from haulage vehicles or conveyer lines will assist in controlling the negative impacts of contamination of the soils either directly or through dirty water movement over unprotected soil.

5.2.3 Decommissioning & Closure Phase

Issue: Net loss of soil volumes and utilisation potential due to change in material status (Physical and Chemical) and loss of nutrient base.

The impacts on the soil resource during the decommissioning and closure phase have both a positive and a negative effect, with:

- The loss of the soils original nutrient status and store and the reduction in the already low organic carbon by leaching of the soils while in storage;
- Erosion and de-oxygenation of materials while stockpiled;
- Compaction and dust contamination due to vehicle movement and wind impacts on the soil while rehabilitating the area;
- Erosion of soils during slope stabilisation and re-vegetation of disturbed areas;
- Contamination of replaced soils by use of dirty water for plant watering and dust suppression on roadways;
- Hydrocarbon or chemical spillage from contractor and supply vehicles;
- Positive impacts of reduction in areas of disturbance and return of soil utilisation potential, uncovering of areas of storage and rehabilitation of compacted materials.

Impact Significance

The impact will **probably** remain the net loss of the soil resource if no intervention or mitigating strategy is implemented. The intensity potential will remain MODERATE to LOW and positive for the medium to short term for all of the activities if there is no active management (rehabilitation and intervention) in the decommissioning phase, and closure will not be possible. The impacts will be confined to the *development* area and its *adjacent* buffer, and is *likely* to happen.

This will result in an irreversible impact that is continuous.

However, with interventions and well planned management, there will be a MODERATE to HIGH positive intensity potential as the soils are replaced and fertilization of the soils is implemented after removal of the infrastructure.

Ongoing rehabilitation during the operational and decommissioning phases will bring about a net long-term positive impact on the soils, albeit that the land capability will likely be reduced to grazing status.

The intensity potential of the initial activities during rehabilitation and closure will be moderate and negative due to the necessity for vehicle movement while removing the demolished infrastructure and rehabilitating the operational footprints. Dust will **potentially** be generated and soil will **probably** be contaminated, compacted and eroded to differing extents depending on the degree of management implemented.

The positive impacts of rehabilitation on the area are the reduction in the footprint of disturbance, the amelioration of the affected soils and oxygenation of the growing medium, the stabilizing of slopes and the revegetation of disturbed areas.

Residual Impacts

On closure of the mining operation the *long-term* negative impact on the soils will be reduced from a significance ranking of MODERATE to LOW if the management plan set out in the Environmental Management Plan is effectively implemented. These impacts will be confined to the development site and its adjacent environments, and is *very likely* to occur.

Chemical amelioration of the soils will have a low but positive impact on the nutrient status (only) of the soils in the medium term.

At closure (obtaining of certificate of closure from authorities) the residual impact should, if all rehabilitation and management efforts have been complied with, result in a positive impact, with the area being returned to a land capability of low intensity grazing or wilderness status, and the use of the land being returned to that of livestock management.

Table 5.2.3a Decommissioning, Closure and Rehabilitation Phase – Impact Significance

CLOSURE AND POST-CLOSURE PHASE									
Activity	**Description of Impact**	**Impact type**	**Spatial Scale**	**Duration**	**Significance**	**Probability**	**Rating**	**Mitigation Measures**	**Interpretation**
Rehabilitation and Closure of the Ash Disposal facility and Associated Infrastructure	Loss of soil nutrient store and organic carbon stores while in storage and while being replaced onto rehabilitated areas - leaching of unprotected materials	Existing	2	4	3	5	3 - MOD	Replacement of nutrient and organic carbon needs and requirements at time of rehabilitation, landscaping of the topographic slope, cultivation of soils and replacement of vegetative cover as soon after replacement of materials as possible. Monitoring of vegetative growth until self sustaining.	The loss of soil nutrient while in storage will need to be replaced. If not adequately accounted for the soils will be restrictive on rehabilitation success.
		Cumulative	2	4	3	5	3 - MOD		On-going loss of nutrient during the replacement phase will result in negative impacts and poor vegetative cover with resultant erosion of resource.
		Residual	2	3	2	3	1.4 - LOW		Well managed and monitored reinplacement of soils along with additives based on sound analytical results will result in a lowering of the impact and a net improvement in the rehabilitated product.
	Contamination of in-situ and stored materials by dirty water outwash and use of dirty water for irrigation of rehabilitated sites	Existing	3	3	3	5	3 - MOD	Management of stormwater control system, and monitoring of water quality used for watering/irrigation of vegetated areas.	Utilisation of poor quality water on rehabilitated soils and/or stockpiles will result in contamination of materials and negative impacts on soil water and possibly the groundwater as well.
		Cumulative	3	3	3	5	3 - MOD		There will be little or no cumulative effects during the closure phase.
		Residual	3	3	2	4	2.1 - MOD		Well managed reinstatement of the soils in the correct sequence and the irrigation of the re-instated vegeative cover with good quality water (SAWQG) will result in a low positive significance rating.
	Hydrocarbon spills from rehabilitation equipment plus potential for compaction of replaced materials, erosion from water and dust and impacts on off site streams and rivers (sedimentary load)	Existing	3	3	3	5	3 - MOD	Maintenance and management of all vehicles, and restrictions on access of vehicles and animals/humans to rehabilitated areas and unprotected soil. Installation of erosion control measures along all drainage ways or water channels.	Utilisation of poorly serviced and maintained vehicles and poor quality water on rehabilitated soils and/or stockpiles will result in contamination of materials and negative impacts on soil and their capability to sustain a vegetative cover. This will in turn result in the loss of soil from the system due to erosion.
		Cumulative	3	3	3	5	3 - MOD		There will be little or no cumulative effects during the closure phase.
		Residual	3	2	2	4	1.9 - LOW		Well managed and maintenance of vehicles and the use of good quality irrigation water on re-instated vegeative cover will result in a low but positive significance rating.
	Addition of fertiliser and composite with potential for contamination to vadose zone and soil water	Existing	3	2	3	3	1.6 - LOW	Assesssmnet of soil requiremets and water holding capabilities and calculation of fertiser requirements as part of rehabilitation planning and implementation programme. Monitoring of water quality at closest waterway.	Over fertilisation of soils and the addition of additives in uncontroolled and monitored manner will impact the soils and soil water negativily.
		Cumulative	3	2	3	3	1.6 - LOW		There will be little or no cumulative effects during the closure phase.
		Residual	3	2	2	4	1.9 - LOW		Small amounts of fertiliser and soil additives on a more frequent basis will result in the uptake of the additions by the vegetation and the maintenance of good quality soil water.
	Uncontrolled access to rehabilitated sites by animal, people and vehicles - compaction and erosion due to loss of vegetative cover (over grazing etc.)	Existing	3	2	3	4	2.1 - MOD	Control of access using fencing and controlled/manned gate entrances.	Uncontrolled acces of vehicles, animals and people will result in the loss of vegetative cover and the loss of the soil cover to erosion by wind and water.
		Cumulative	3	2	3	4	2.1 - MOD		There will be little or no cumulative effects during the closure phase.
		Residual	3	2	2	4	1.9 - LOW		Controlling of access to the rehabilitated sites and ADF will give the vegetation time to establish and form a natural cover to the soils. This will have a net positive impact on the soils and their capability to sustain cover.

6. ENVIRONMENTAL MANAGEMENT PLAN

6.1 General

In accordance with the International Principles (IFC Performance Principles), and the concept of sustainability, it is incumbent on any developer to not only assess and understand the possible impacts that a development might cause, but to also propose and table management measures that will aid in minimising and where possible mitigate the effects.

The management of the natural resources (soils) have been assessed on a phased basis (construction, operation and decommissioning/closure) in keeping with the impact assessment (EIA) philosophy, while the Environmental Management Plan (EMP) has been designed as a working plan and utilisable guide for soil and land management.

The results tabled are based on the site specifics of geomorphology (topography, altitude, attitude, climate and ground roughness) and the activities as described in the project design criteria as the basis for the impact assessment and the effects on the environment.

The plan gives recommendations on the stripping and handling of the soils throughout the life of the development along with recommendations for the utilization of the soils for rehabilitation at closure.

It has been assumed that all infrastructure will be removed and that the areas that were affected will be returned to as close as possible their pre-construction state (topographic levels, wilderness/conservation or low intensity grazing status – Refer to the Chamber of Mines Land Classification System (Refer to Section 2 - Table 2.2.1 of the Baseline Study), albeit that an Ash Disposal Facility will inevitably remain as a permanent feature.

The concept of stripping and storage of all "Utilisable" soil is recommended as a minimum requirement and as part of the overall Soil Utilisation Philosophy.

In terms of the "Minimum Requirements", **usable or utilisable soil** is defined here as all soil above an agreed subterranean cut-off depth defined by the project soil scientist, and will vary for different forms of soil encountered in a project area and the type of project being considered. It does not differentiate between topsoil (orthic horizon) and other subsoil horizons necessarily.

The following soil utilisation guidelines **(*all be they generic*)** should be incorporated into the management plan wherever possible:

- Over areas of deep excavation *strip all usable soil* as defined (700mm) in terms of the soil classification and stockpile as berms or low, terraced stockpiles. Alluvial soils should be stockpiled separately from the colluvial (shallower) and in-situ derived materials, which in turn should be stored separately from any calcrete/ferricrete material, while the soft overburden is stored as a separate unit and as a defined stockpiles of less than 15m in height preferably. Protect from contamination and erosion by rock cladding or vegetation cover and adequate drainage of surface runoff.

At *rehabilitation* replace the soft overburden followed by the calcrete/ferricrete, compact and replace the soil to appropriate soil depths, and cover areas to achieve an appropriate topographic aspect and attitude that will achieve a free draining landscape as close as possible to the pre-mining/construction land capability rating.

- Over areas planned for less invasive Structures (Offices, Workshops etc) and any material stockpile or storage, *strip the top 500 mm* of usable soil over all affected areas including terraces and *strip remaining usable soil and calcrete (if present in profile)* where founding conditions require further soil removal.

  Store the soil in stockpiles or berms of not more than 1.5 m around infrastructure area ready for closure rehabilitation purposes. Stockpile hydromorphic (wet) soils separately from the dry materials, and the "calcrete" separately from all other materials.

  Protect all stockpiles from water and wind erosion (loss of materials) and contamination by dust and runoff water. Clad stockpiles with larger rock or vegetate the stored materials.

  At closure/rehabilitation, remove all large boulders and gravel from the rehabilitated landscape and place at the base/bottom of the foundations or open pit profile so that they do not interfere with the tillage and cultivation of the final surface. Remove foundations to a maximum depth of 1m. Replace soil to appropriate soil depths, and over disturbed areas and in appropriate topographic position to achieve pre-development land capability and land form where possible.

- Over areas of Tailings Storage facilities, Ash Disposal Facilities, Waste Rock Dumps and all Heavy Vehicle Haulage Roads and Major Access Routes, *strip usable soil* to a *depth of 750 mm where possible and/or* in areas of *arable soils,* and *between 300mm and 500mm* in areas of *soils with grazing land capability.* Stockpile hydromorphic soils separately from the dry and friable materials.

  Before *rehabilitation* remove all gravel and other rocky material and recycle as construction material or place in open voids. Remove foundations to a maximum depth of 1m. Replace soil to appropriate soil depths and in appropriate topographic position so as to achieve pre-mining land capability. Protect the stored materials from erosion and contamination using vegetation or rock cladding.

- Over areas to be utilized for General Access Roads (light delivery vehicles), Laydown Pads and any Conveyencing servitudes (Above ground pipelines and power line servitudes) *strip the top 150 mm* of usable soil over all affected areas and stockpile in longitudinal stockpile or berms upslope of the facilities. Protect from erosion and contamination.

6.2 Construction Phase

The construction methods to be used and the final End Land Use (ELU) at rehabilitation and closure are important in deciding how the utilisable soils need to be stripped and retained, and ultimately how much of the materials will be needed for the rehabilitation (stripping volumes).

Failure to remove and store the utilisable materials will result in the permanent loss of the growth medium.

Making provision for retention of utilisable material for the decommissioning and/or during rehabilitation will not only save significant costs at closure, but will ensure that additional impacts to the environment do not occur.

The depths of utilisable materials on Site “H” vary between 300mm and greater than 1,200mm.

Due to the shallow soil depths on the more rocky areas it is recommended that sufficient materials are removed from the areas were significant soil depths are present and do exist, so that the shallow areas can be adequately resorted during rehabilitation and at closure.

For the ADF footprint as a whole, and the nature of the activities that will take place as support infrastructure to the ash disposal it is recommended that at least 750mm of soil should be removed/stripped wherever possible.

The conveyencing route and access roads/ways will require that only 500mm of soil is removed and stored.

The areas confirmed as low sensitivity and or outside of the No Go zones are sufficiently similar that they can be stored as one soil group (Refer to Figure 5 – Soil Sensitivity Map). However, the Highly Sensitive and “No Go” areas (wetland areas) should not be impacted unless absolutely necessary, and then only if the necessary permissions have been obtained (licenses etc.).

Table 6.2 is a plan for soil utilisation during the construction phase.

Table 6.2 — Construction Phase – Soil Utilisation Plan

Phase	Step	Factors to Consider	Comments
Construction	Delineation of areas to be stripped		Stripping will only occur where soils are to be disturbed by activities that are described in the design report, and where a clearly defined end rehabilitation use for the stripped soil has been identified.
	Reference to biodiversity action plan		It is recommened that all vegetation is stripped and stored as part of the utilizable soil. However, the requirements for moving and preserving fauna and flora according to the biodiversity action plan should be consulted.
	Stripping and Handling of soils	Handling	Soils will be handled in dry weather conditions so as to cause as little compaction as possible. Utilisable soil (Topsoil and upper portion of subsoil B2/1) must be removed and stockpiled separately from the lower "B" horizon, with the ferricrete layer being seperated from the soft/decomposed rock, and wet based soils seperated from the dry soils if they are to be impacted.
		Stripping	The "Utilizable" soil will be stripped to a depth of 750mm or until hard rock/ferricrete is encountered. These soils will be stockpiled together with any vegetation cover present (only large vegetation to be removed prior to stripping). The total stripped depth should be 750mm, wherever possible.
	Delineation of Stockpiling areas	Location	Stockpiling areas will be identified in close proximity to the source of the soil to limit handling and to promote reuse of soils in the correct areas. All stockpiles will be founded on stabilized and well engineered "pads"
		Designation of Areas	Soils stockpiles will be demarcated, and clearly marked to identify both the soil type and the intended area of rehabilitation.

This "Soil Utilisation Plan" is intimately linked to the "development plan", and it should be understood that if the plan of construction changes, these recommendations will probably have to change as well.

6.3 Operational Phase

The operational phase will see very little change in the development requirements, with the footprint of disturbance remaining constant, albeit that the temporary infrastructure might become redundant and rehabilitation of these features might be possible.

Maintenance and care of the soil and land resources will be the main management activity and objective required during the operational phase. Management of material loss, compaction and contamination are the main issues of consideration. Table 6.3 give details and recommendations for the care and maintenance of the resource during the operational phase.

The semi-arid climate and unique character of the soils in the study area require that the site specific and unique natural phenomena should be used to the advantage of the project.

Working with or on the differing soil materials (all of which occur within the areas that are to be disturbed) will require better than average management and careful planning if rehabilitation is to be successful, and it is important that the sensitive and highly sensitive materials are avoided wherever possible.

Care in removal and stockpiling/storage of the "Utilisable" soils, and protection of materials which are derived from the wet based soil is imperative to the success of sustainable rehabilitation in these areas, with the soil water (near surface water) held within the profile by this inhibiting layer being of great importance and integral to the success of the biodiversity and ecological systems and services.

Table 6.3 Operational Phase – Soil Conservation Plan

Phase	Step	Factors to Consider	Comments
Operation	Stockpile management	Vegetation establishment and erosion control	Enhanced growth of vegetation on the Soil Stockpiles and berms will be promoted (e.g. by means of watering and/or fertilisation), or a system of rock cladding will be employed. The purpose of this exercise will be to protect the soils and combat erosion by water and wind.
		Storm Water Control	Stockpiles will be established/engineered with storm water diversion berms in place to prevent run off erosion.
		Stockpile Height and Slope Stability	Soil stockpile and berm heights will be restricted where possible to <2.0m so as to avoid compaction and damage to the soil seed pool. Where stockpiles higher than 1.5m cannot be avoided, these will be benched to a maximum height of 15m. Each bench should ideally be 1.5m high and 2m wide. For storage periods greater than 3 years, vegetative (vetiver hedges and native grass species - refer to Appendix 1) or rock cover will be essential, and should be encouraged using fertilization and induced seeding with water and/or the placement of waste rock. The stockpile side slopes should be stabilized at a slope of 1 in 6. This will promote vegetation growth and reduce run-off related erosion.
		Waste	Only inert waste rock material will be placed on the soil stockpiles if the vegetative growth is impractical or not viable (due to lack of water for irrigation etc.). This will aid in protecting the stockpiles from wind and water erosion until the natural vegetative cover can take effect.
		Vehicles	Equipment, human and animal movement on the soil stockpiles will be limited to avoid topsoil compaction and subsequent damage to the soils and seedbank.

6.4 Decommissioning and Closure

The decommissioning and closure phase will see:

- The removal of all infrastructure;
- The demolishing of all concrete slabs/plinths and the ripping of any hard/compacted surfaces;
- The backfilling of all voids and deep foundations and the reconstruction of the required barrier layer (compaction of ferricrete and clay rich materials) wherever feasible and engineering possible;
- Topdressing of the disturbed and backfilled areas with the stored “utilisable” soil ready for re-vegetation;
- Capping of the final phases of the disposal facility (ash disposal) and waste piles with utilisable soil;
- Vegetation of soil stockpiles and waste piles;
- Fertilisation and stabilisation of the backfilled and final cover materials (soil and vegetation) and
- The landscaping of the replaced soils to be free draining.

There will be a positive impact on the soil and land capability environments as the area of disturbance is reduced, the soils are returned to a state that can support low intensity wildlife grazing or sustainable conservation and the impacts of compaction and erosion are mitigated.

Table 6.4 is a summary of the proposed management and mitigation actions recommended.

Table 6.4 Decommissioning and Closure Phase – Soil Conservation Plan

Phase	Step	Factors to Consider	Comments
Decommissioning & Closure	Rehabilitation of Disturbed land & Restoration of Soil Utilization	Placement of Soils	Stockpiled soil will be used to rehabilitate disturbed sites either ongoing as disturbed areas become available for rehabilitation and/or at closure. The utilizable soil (500mm to 750mm) removed during the construction phase, must be redistributed in a manner that achieves an approximate uniform stable thickness consistent with the approved post development end land use (Conservation land capability and/or Low intensity grazing), and will attain a free draining surface profile. A minimum layer of 300mm of soil will be replaced.
		Fertilization	A representative sampling of the stripped and stockpiled soils will be analysed to determine the nutrient status and chemistry of the utilizable materials. As a minimum the following elements will be tested for: EC, CEC, pH, Ca, Mg, K, Na, P, Zn, Clay% and Organic Carbon. These elements provide the basis for determining the fertility of soil. based on the analysis, fertilisers will be applied if necessary.
		Erosion Control	Erosion control measures will be implemented to ensure that the soil is not washed away and that erosion gulleys do not develop prior to vegetation establishment.
	Pollution of Soils	In-situ Remediation	If soil (whether stockpiled or in its undisturbed natural state) is polluted, the first management priority is to treat the pollution by means of in situ bioremediation. The acceptability of this option must be verified by an appropriate soils expert and by the local water authority on a case by case basis, before it is implemented.
		Off site disposal of soils.	If in situ treatment is not possible or acceptable then the polluted soil must be classified according to the Minimum Requirements for the Handling, Classification and Disposal of Hazardous Waste (Local Dept of Water Affairs) and disposed of at an appropriate, permitted, off-site waste facility.

6.5 Monitoring and Maintenance

Nutrient requirements reported in this document are based on the monitoring and sampling of the soils at the time of the baseline survey. These values will definitely alter during the storage stage and will need to be re-evaluated before being used during rehabilitation

During the **rehabilitation exercise**, preliminary soil quality monitoring should be carried out to accurately determine the fertiliser and pH requirements that will be needed.

Additional soil sampling should also be carried out annually after rehabilitation has been completed and until the levels of nutrients, specifically magnesium, phosphorus and potassium, are at the required levels for sustainable growth.

Once the desired nutritional status has been achieved, it is recommended that the interval between sampling is increased. An annual environmental audit should be undertaken. If growth problems develop, ad hoc, sampling should be carried out to determine the problem.

Monitoring should always be carried out at the same time of the year and at least six weeks after the last application of fertilizer.

Soils should be sampled and analysed for the following parameters:

pH (H_2O)	Phosphorus (Bray I)	
Electrical conductivity	Calcium mg/kg	
Cation exchange capacity	Sodium mg/kg;	
Magnesium mg/kg;	Potassium mg/kg	Zinc mg/kg;
Clay, sand and Silt	Organic matter content (C %)	

The following maintenance is recommended:

- The area must be fenced, and all animals kept off the area until the vegetation is self-sustaining;
- Newly seeded/planted areas must be protected against compaction and erosion (Vetiver hedges etc.);
- Traffic should be limited were possible while the vegetation is establishing itself;
- Plants should be watered and weeded as required on a regular and managed basis were possible and practical;
- Check for pests and diseases at least once every two weeks and treat if necessary;
- Replace unhealthy or dead plant material;
- Fertilise, hydro seeded and grassed areas soon after germination, and
- Repair any damage caused by erosion;

LIST OF REFERENCES

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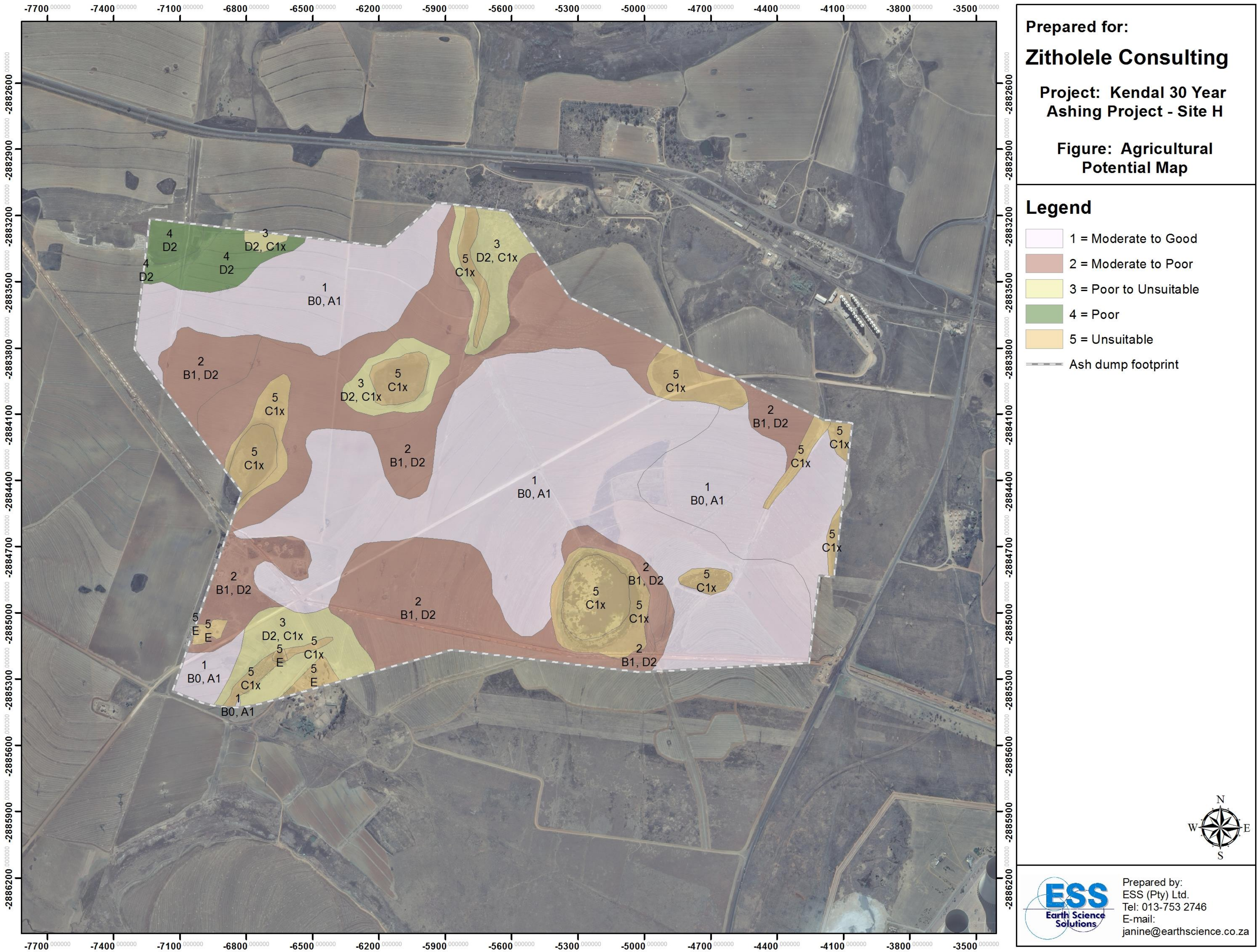
APPENDIX 1

SITE MAPS A3)
(Soils, Soil Groups and Land Capability)


Prepared for:
Zitholele Consulting
Project: Kendal 30 Year Ashing Project - Site H
Figure: Agricultural Potential Map
Legend
1 = Moderate to Good
2 = Moderate to Poor
3 = Poor to Unsuitable
4 = Poor
5 = Unsuitable
Ash dump footprint
1 B0, A1
2 B1, D2
3 D2, C1x
4 D2
5 C1x
5 E
N
S
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W
ESS
Earth Science Solutions
Prepared by:
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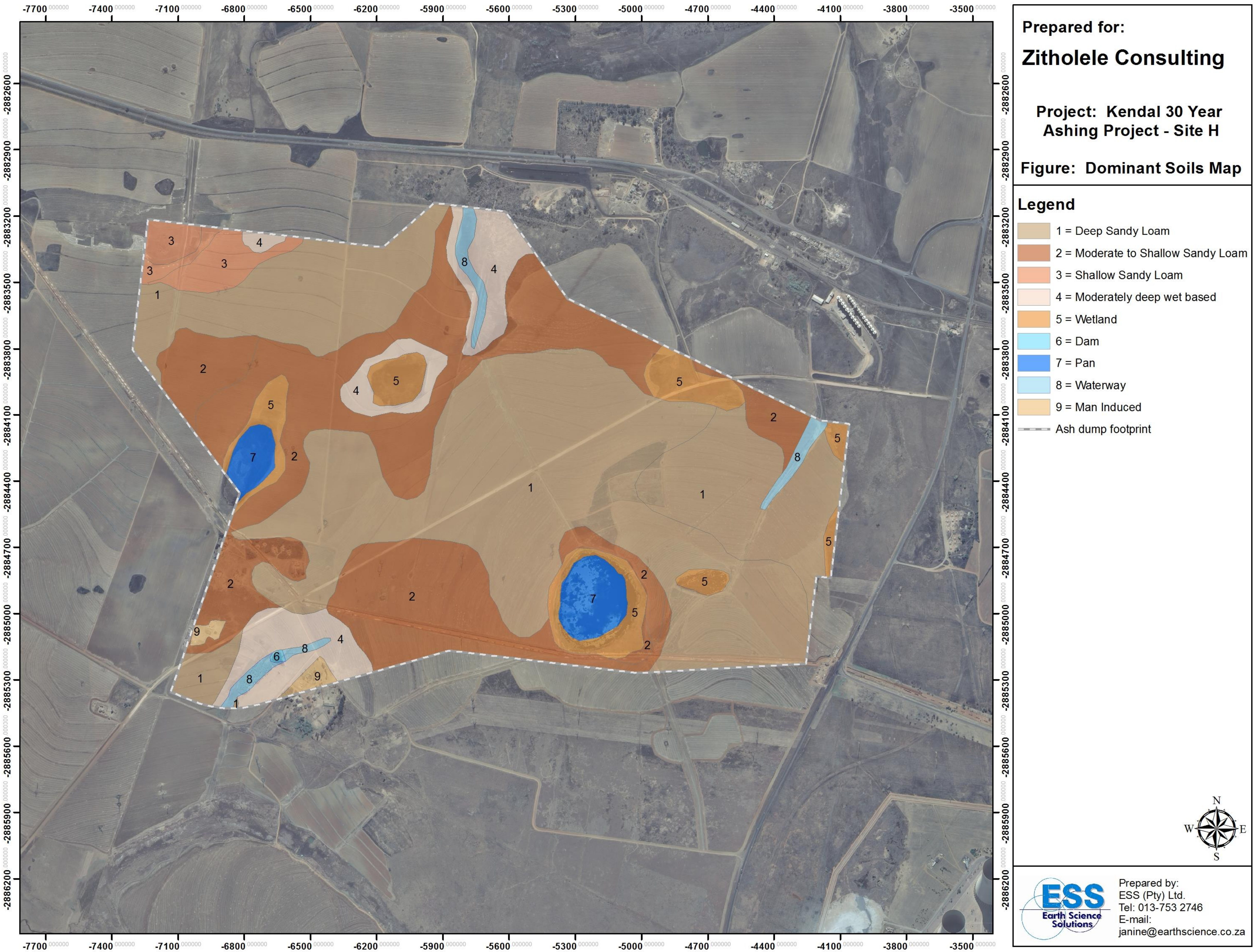
Prepared for:
Zitholele Consulting
Project: Kendal 30 Year Ashing Project - Site H
Figure: Dominant Soils Map
Legend
1 = Deep Sandy Loam
2 = Moderate to Shallow Sandy Loam
3 = Shallow Sandy Loam
4 = Moderately deep wet based
5 = Wetland
6 = Dam
7 = Pan
8 = Waterway
9 = Man Induced
Ash dump footprint
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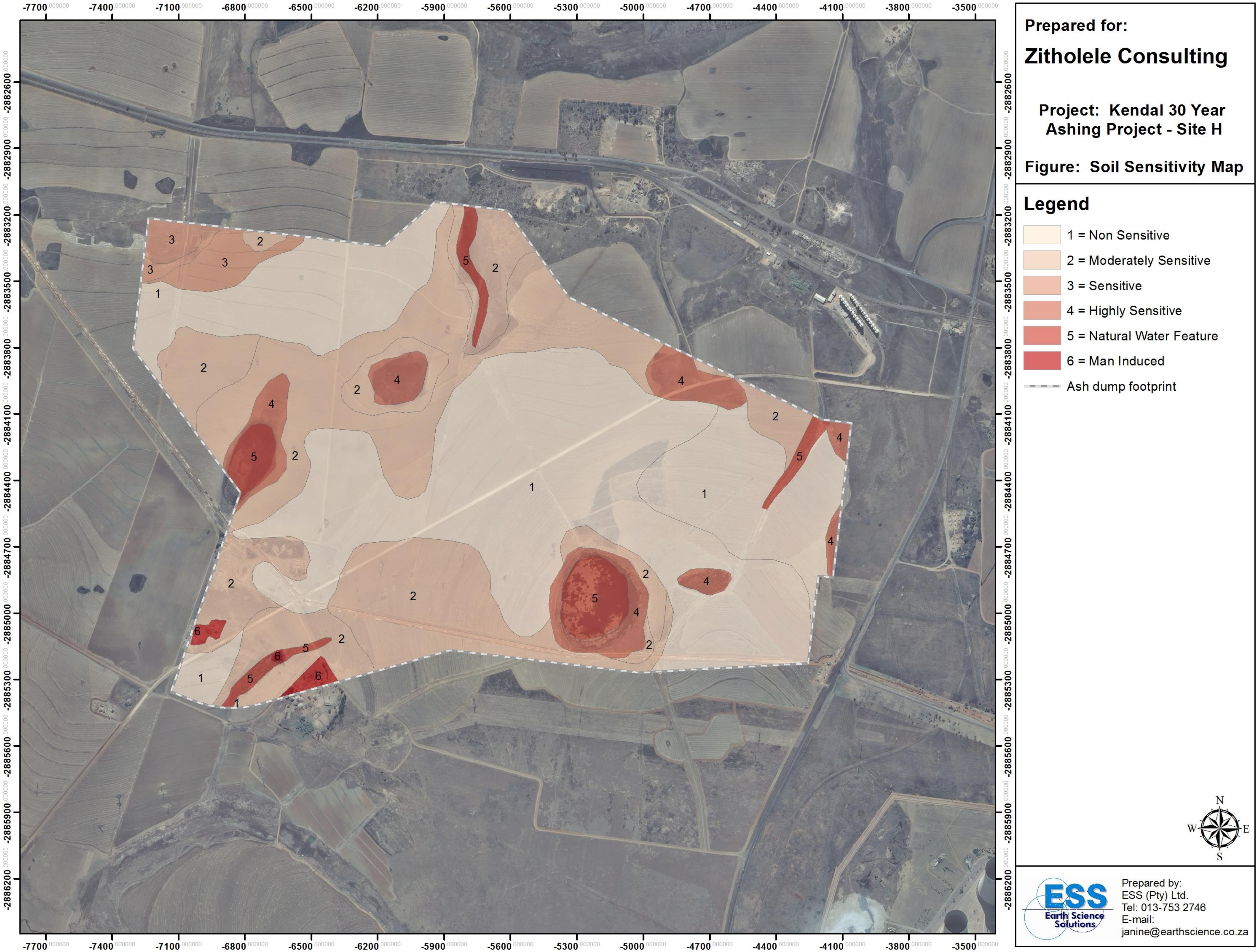
Prepared for:
Zitholele Consulting
Project: Kendal 30 Year Ashing Project - Site H
Figure: Soil Sensitivity Map
Legend
1 = Non Sensitive
2 = Moderately Sensitive
3 = Sensitive
4 = Highly Sensitive
5 = Natural Water Feature
6 = Man Induced
Ash dump footprint
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APPENDIX 2

VETIVER GRASS

THE VETIVER SYSTEM

A PROVEN SOLUTION

The Vetiver Network International - www.vetiver.org

VETIVER GRASS

A HEDGE AGAINST EROSION

The Vetiver Network International - www.vetiver.org

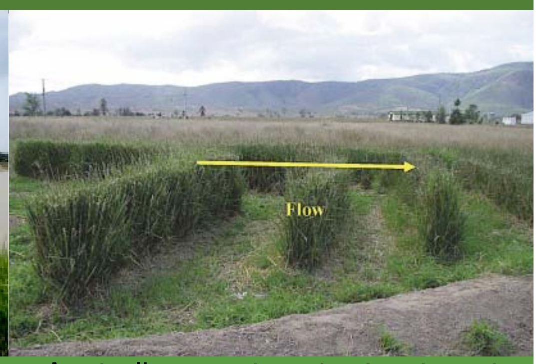

Malaysia - highway stabilization


India - beach stabilization


Fiji - 2m high vetiver created terrace


Ethiopia - soil conservation


Cambodia - river bank stabilization



Australia - wastewater treatment

The problems we face are growing at a pace that challenges our ability to solve them

- Soil loss results in physical, chemical, and biological degradation and loss of ability to produce food.
- Land slides, unstable slopes and flooding destroy agricultural land and valuable infrastructure.
- Siltation of drains, lakes, reservoirs, and rivers reduce storage capacity and can result in flooding.
- Overuse and misuse of large areas of land, and contamination by toxic runoff from mine dumps, landfills, feedlots, salinization, etc.., require extensive reclamation programs.
- Water polluted by mineral or organic sediments as well as the pollutants mentioned above detrimentally affect drinking water supplies, fresh and saltwater fisheries, and coral reefs.
- Decreased groundwater recharge in watersheds results in local water shortages.
- Inattention to site stabilization and maintenance results in infrastructure failure and losses.

Solutions are often too complex or costly given existing resources and capacity

- The complexity and high cost of engineering and structural designs; ambitious and impracticable environmental protection and remedial practices - often due to over demanding design engineers and supervisors - and unnecessary high-end quality control measures; as well as, amongst others, bureaucratic accounting and bidding procedures.
- Low potential for sustainability due to lack of funds for maintenance, unsuitability to local conditions/ capacity, or need for continuous subsidies to maintain effectiveness.

Many of these problems share a common solution in THE VETIVER SYSTEM

The Vetiver System (VS)

- Consists of a simple vegetative barrier (a hedge) comprising upright, rigid, dense, and deeply-rooted clump grass, that slows runoff, allowing sediments to stay on site, eventually forming natural terraces.
- Vetiver grass is already found in more than 120 countries throughout the tropics and sub-tropics.
- It has been used for more than a century in many Asian, African, and Caribbean countries as a traditional "soil binding" technology.
- Today, the VS is used for soil and moisture conservation, bioengineering, and for bioremediation.

It is not weedy or invasive

- Hedges are propagated and established vegetatively. **Analyses show that recommended cultivars of *Chrysopogon zizanioides* (south India type) are sterile and are not invasive.**

Deep, tough roots

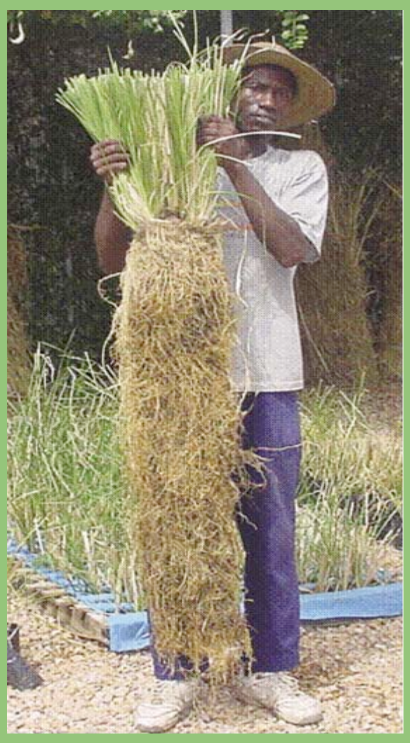
- Vetiver's deep, massive fibrous root system can reach down to two to three meters in the first year.
- This massive root system is likened to "*living nails*", binding the soil together.
- The measured maximum resistance of vetiver roots in soils is equivalent to one-sixth that of mild steel (75 Mpa); stronger than most tree roots; improves soil shear strength by as much as 39%
- The fibrous mat of roots strengthens earthen structures and removes many contaminants from soil and soil water.
- Closely planted slips grow into dense hedgerows with a deep, tough root systems. They can withstand inundation, and effectively reduce flow velocities, forming excellent filters that prevent soil loss.

THE PLANT -- VETIVER GRASS -- *Vetiveria zizanioides L (Nash) recently reclassified* ***Chrysopogon zizanioides L (Roberty)***

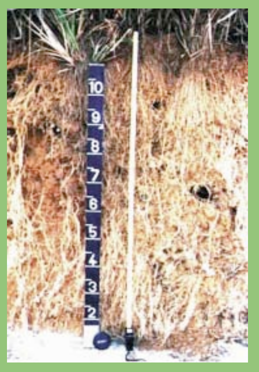

Chrysopogon zizanioides L (Roberty) previously named *Vetiveria zizanioides L (Nash)* common name: ***Vetiver Grass***


Planting slip


Tissue cultivation of vetiver grass


6 month vetiver root grown in Senegal


Cross section through a two year old hedgerow. Note sediment build up over original top soil (brown line)


Longitudinal section through hedgerow


Newly planted vetiver hedgerow

Large differences occur between the roots of vetiver grass species and cultivars. Compare *C. zizanioides* (upper) with *C. nemoralis* (lower)


Indian vetiver nursery of containerized plants


Planting containerized vetiver on steep highway fill slope in Malaysia


Vetiver inflorescence. In many cases vetiver never flowers, but when it does, it produces rather beautiful non-fertile flowers

WHY VETIVER GRASS

For a plant to be useful for agriculture and biological engineering, and be accepted as safe, it should have as many as possible of the following characteristics:

- Its seed should be sterile, and the plant should not spread by stolons or rhizomes, and therefore not escape and become a weed.
- Its crown should be below the surface so it can resist fire, over grazing, and trampling by livestock.
- It should be capable of forming a dense, ground level, permanent hedge, as an effective filter, preventing soil loss from runoff. Apparently only clones will grow 'into' each other to form such a hedge.
- It should be perennial and permanent, capable of surviving as a dense hedge for decades, but only growing where we plant it.
- It should have stiff erect stems that can, at minimum, withstand flowing water of 1 foot (30 cm) depth that is moving at 1 foot per second (0.3 meters/second).
- It should exhibit xerophytic and hydrophytic characteristics if it is to survive the extremes of nature. Vetiver grass, once established, is little affected and highly tolerant of droughts or floods.
- It should have a deep penetrating root system, capable of withstanding tunnelling and cracking characteristics of soils, and should the potential to penetrate vertically below the plant to at least three meters.
- It should be capable of growing in extreme soil types, regardless of nutrient status, pH, sodicity, acid sulphate or salinity, and toxic minerals. This includes sands, shales, gravels, mine tailings, and even more toxic soils.
- It should be capable of developing new roots from nodes when buried by trapped sediment, and continue to grow upward with the rising surface level, forming natural terraces.
- It should not compete with the crop plants it is protecting.
- it should not be a host (or intermediate host) for undesirable pests or diseases of any other plants.
- It should be capable of growing in a wide range of climates -- from 300 mm of rainfall to over 6,000 mm -- from air temperatures of -15º C (where the soil does not freeze) to more than 55º C. It should be able to withstand long and sustained droughts (>6 months).
- It should be cheap and easy to establish as a hedge and easily maintained by the user at little cost.
- It should be easily removed when no longer required.

Vetiver Grass cultivars used around the world for essential oil production, originating from south India, have all these characteristics.


Dense crown of a vetiver grass clump from which roots and shoots emerge


After a fire vetiver hedge remains vertical and quickly recovers with new growth


Erosion sediment trapped by a vetiver hedgerow in Madagascar.

Closely spaced (15 cm between plants at planting) hedgerow at left assures a properly dense hedge

Very dense and very effective vetiver hedgerow

VS FOR AGRICULTURE

- **On-farm** - in modern and traditional agriculture VS is used to trap sediments, control runoff, increase soil moisture recharge, and stabilize soils during intense rainfall and floods. There is only minimal competition with adjacent perennial and annual crops for moisture or nutrients. VS is used for wind erosion control, forage, and pest control.
- **On-farm** - VS protects rural structures such as roads, ponds, drains, canals and building sites. Also used for land and gully rehabilitation.
- **Off-farm** - VS plays a vital role in watershed protection at large scales - slowing down and spreading rainfall runoff, recharging groundwater reserves, reducing siltation of drainage systems, lakes and ponds, reducing agrochemical loading into groundwater and watercourses, and for rehabilitation of misused land.






Top left: Vetiver hedgerows protecting farm crops on steep slopes in the highlands of N.E. Thailand

Top center: Vetiver hedgerow on Darling Downs, Australia, used to reduce erosive power of flooding on flat land -- as a result more land can be cropped each year

Top right: Farmers from Gundalpet, India, have used vetiver for centuries to reduce soil loss, conserve moisture, provide forage, and increase groundwater recharge

Bottom left: Vetiver hedgerow used to protect crops from high winds in Pintang Island, China

Bottom center: Vetiver used to stabilize a farm road in Malaysia

Bottom right: A irrigation drain/canal stabilized by vetiver hedgerow

THE VETIVER SYSTEM

A PROVEN SOLUTION

The Vetiver Network International - www.vetiver.org

VETIVER GRASS

A HEDGE AGAINST EROSION

The Vetiver Network International - www.vetiver.org

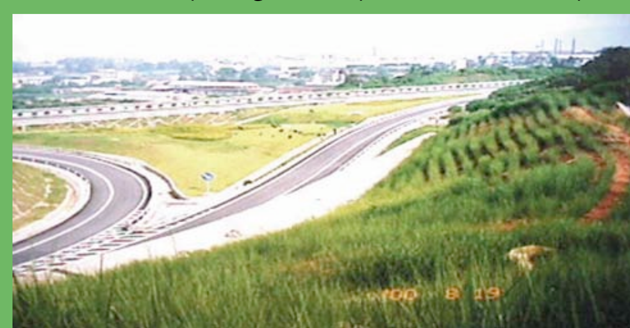
VS FOR BIO-ENGINEERING

- For the stabilization and protection of infrastructure (roads, railroads, and building sites) VS is proven effective, efficient, and low cost when compared to other 'hard' engineering alternatives using cement, rock, and steel. Vetiver grass roots have an Mpa of 75 (1/6 the strength of mild steel) and will improve soil shear strength at a depth of 0.5 meters by as much as 39%. VS costs from 55% to 85% less than traditional engineering systems. **For successful applications cultivars of *Chrysopogon zizanioides* originally from south India should be used**. These cultivars are of the same genotype as Monto and Sunshine, and are **non-invasive.** They have a more massive root structure than non sterile *C.zizanioides* accessions from north India, Africa (*C.nigratana*) and Thailand (*C.nemoralis*)



The KEY to successful VS applications for infrastructure is the availability of large quantities of good quality vetiver planting material. Above, from left to right, are nurseries from Senegal (containerized), China (bare rooted) and Thailand (from in vitro plantlets)

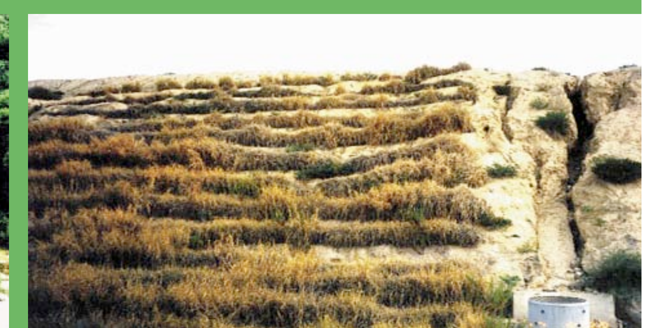
Venezuela - rehabilitation of bauxite mine tailings. The soils are very acid and prone to slippage. High levels of fertilizer assure good growth



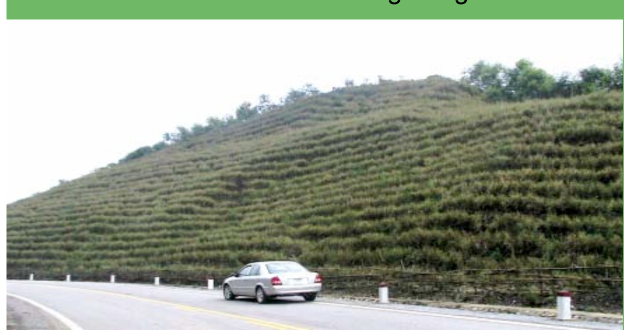
China - expressway stabilization. This cut was prone to massive slip. Stabilization with VS has given complete protection

China - unstable highway fill prior to VS treatment. Road stability was so bad in untreated state that major lateral cracks in the pavement occurred

China - same fill less than a year later. After another two years this fill became fully forested. Untreated cut in background

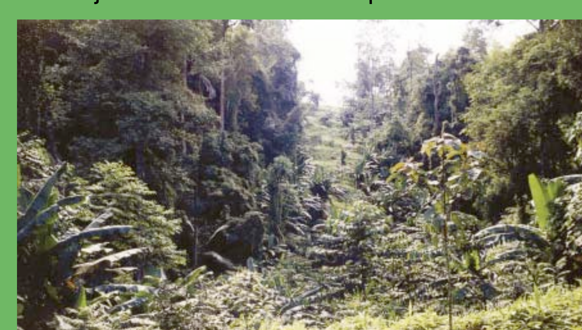


Spain - unstable and eroding highway fill treated with VS. Untreated eroded fill on right. VS grows well under low rainfall Mediterranean climate



Vietnam: the Ho Chi Minh Highway has been stabilized with vetiver grass. The batters and fills are stable and withstand cyclonic rainfall events

Vietnam - Ho Chi Minh Highway - with and without vetiver stabilization



Thailand - a gas pipeline was laid through tropical forest. On steep slopes the right of way was stabilized with vetiver - native plants regenerated

Disaster mitigation - this railroad in Madagascar was closed down by frequent cyclone damage. Stabilization with vetiver was vital in its rehabilitation

Congo D.R. - huge gullies that destroy urban areas and houses can be rehabilitated and stabilized using the Vetiver System.

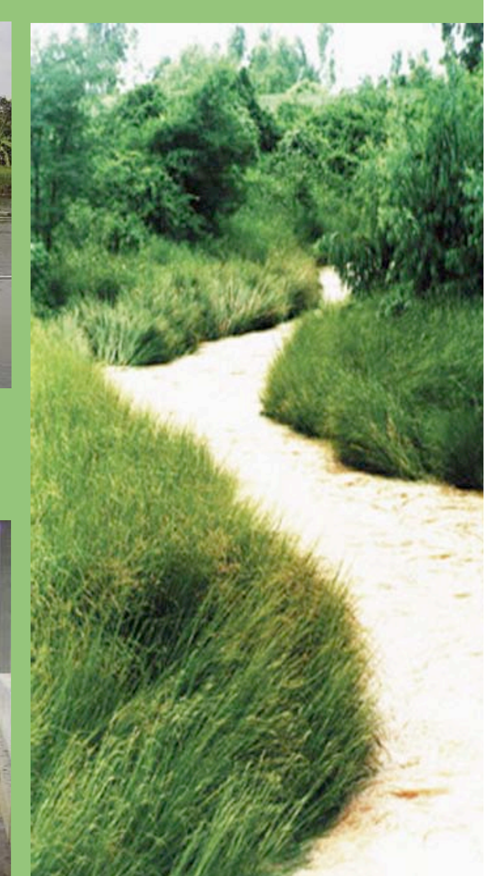
VS FOR WATER RELATED APPLICATIONS

- VS protects ponds, reservoirs, and rivers banks from erosion caused by wave action, it strengthens earthen dams against collapse, and it reduces maintenance costs and ensures the integrity of dam walls, canal and river banks, and drains.
- VS improves groundwater recharge through improved infiltration and reduced rainfall runoff, and the quality of water by removing sediments and chemicals.

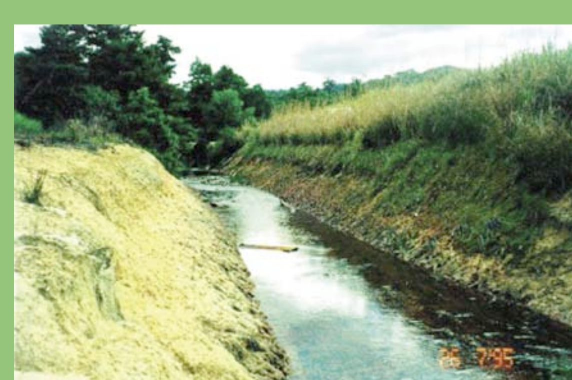
Venezuela - Vetiver withstands flooding for long periods. This grass was flooded for 8 months. Vetiver one month after flood receded

China - VS used to stabilize a small river bank located behind hedge allowing the safe production of crops

Vietnam - Vetiver is increasingly used to stabilize the banks of fishponds and to purify pond water



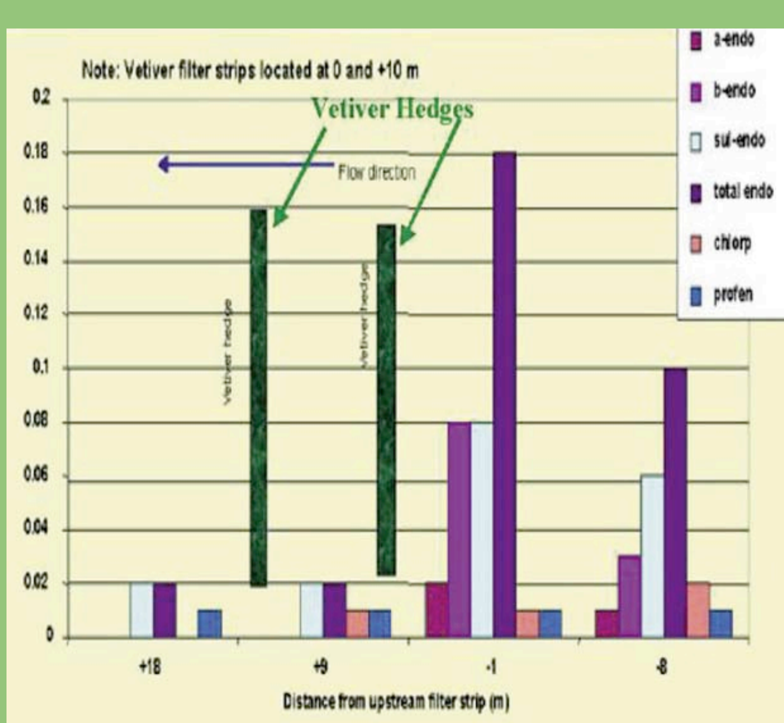
Zimbabwe - a fast flowing stream protected from stream bank erosion using VS application



Australia - VS protects the right hand bank of a drain cut through acid sulphate soils of Queensland. Note left hand bank is devoid of any vegetation

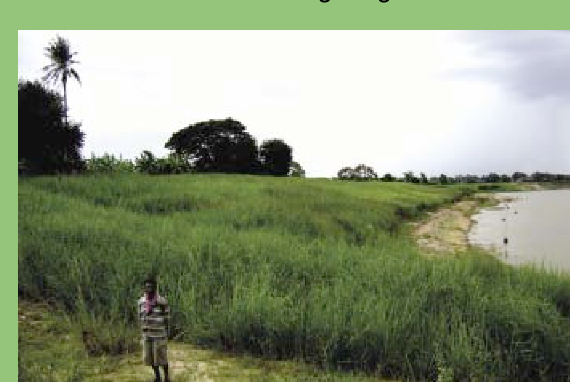
China - partially submerged vetiver grass used to stabilize the draw-down slope of a reservoir in Guangdong Province

Australia - this river bank and bridge abutment have been stabilized with vetiver. Vetiver is an excellent interface for concrete and soil



Australia - schematic of research results showing dramatic drop of pesticide levels as pesticide laden water moves through vetiver hedges from right to left. (Green columns = hedges - all other columns pesticide levels)

Cambodia - This very large bank on the Mekong River has been under continuous erosion. The land owner with assistance from TVNI is stabilizing using vetiver hedgerows.



Cambodia - the bank in the previous image has been reshaped and planted with vetiver hedgerows. Very good growth seven months after planting.

Vietnam - cyclone damage to sea dykes is a major problem. VS has been applied successfully for disaster mitigation

Vietnam - the left hand bank of the canal has been reshaped and stabilized with vetiver, the right bank has yet to be treated.

VS FOR BIO-REMEDIATION

- Onsite and offsite pollution control from wastes and contaminants is a breakthrough application of VS for environmental protection. Vetiver is being used to rehabilitate a large copper mine in China, coal mines in Indonesia, diamond mine spoils in South Africa, to control erosion and leachate from municipal landfills in China…. and more.
- Research has clearly established vetiver's tolerance to extremely high levels of Al, Mn, As, Cd, Cr, Ni, Cu, Pb, Hg, Se, and Zn.
- Vetiver has been used to reclaim soils and increase site productivity in places that were previously believed to be totally unproductive.

Vetiver grass will remove phosphate and nitrate from polluted water. The beaker on the left is before treatment; on the right 4 days later 90% P and 94% N removed

Australia - VS used as a buffer to absorb seeping sewage from this holiday camp site thus reducing runoff and smells

Australia - VS used to stabilize a gold slimes waste area. The hedges reduce the incidence of wind-blown, cyanide-polluted dust

Australia - VS used hydroponically on a pig effluent pond to reduce high levels of phosphate and nitrate

VS FOR OTHER USES

- In disaster mitigation and vulnerability reduction, VS has a crucial role to play…. "*The storms were terrible. [Afterward there were] landslides, roads destroyed, agricultural lands washed away; but, where there were vetiver barriers, everything seemed normal".* (pers. comm. Mr. E. Mas, USDA/NRCS after Hurricane George, Puerto Rico)
- For handicrafts, perfumes, and medicinal purposes.
- For paper making, mulch, thatch, reinforcing bricks, biofuel, pest control, carbon sequestering, and many other uses.

Thailand - a selection of handicrafts, including handbags, vases, lamp shades, book covers, hats and other crafts from vetiver grass leaves and stems

Zimbabwe - a nicely thatched meeting house using vetiver grass thatch. The thatch will last three times as many years due to its resistance to insects and fungus attack

ACT NOW! **Contact TVNI for additional technical information.**

The Vetiver Network International
709 Briar Rd., Bellingham, WA 98225 USA

Tel/Fax: (001) 360-671-5985
E-mail: coordinator@vetiver.org

Home Page: http//www.vetiver.org
Vetiver Clients Gallery: http://picasaweb.google.com/VetiverClients
Vetiver Picture Gallery:http://picasaweb.google.com/VetiverNetwork
Blog: http://vetivernetinternational.blogspot.com

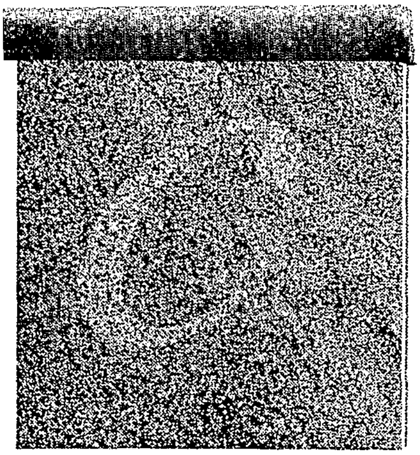
The Vetiver Network (TVNI) is a nonprofit foundation under United States code 501 (c) (3). It is a volunteer organization that promotes the use of the Vetiver System through dissemination of information and networking worldwide. TVN has helped established over 25 regional and country-based affiliated networks.

Contact your local vetiver network at:

FOR SUCCESSFULL VETIVER SYSTEMS APPLICATION ONLY USE CULTIVARS OF *CHRYSOPOGON ZIZANIOIDES* WITH CHARACTERISTICS OF SOUTH INDIAN GENOTYPES - SUCH AS SUNSHINE, MONTO, KARNATAKA, FIJI, MADUPATTY. THESE NOT ONLY HAVE GOOD ROOT SYSTEMS, BUT ARE KNOWN TO BE NON-INVASIVE AND ARE EXTENSIVELY RESEARCHED

APPENDIX 3

FERRICRETE CLASSIFICATION



PETROLOGICAL AND GEOCHEMICAL CLASSIFICATION OF LATERITES

Yves Tardy,[1,3,4] *Jean-Loup Boeglin,*[2,3] *André Novikoff*[2] *and Claude Roquin*[3]

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Abstract

In this classification of lateritic covers four major types are distinguished: ferricretes, latosols, conakrytes and bauxites.

In ferricretes, hematite is associated with kaolinite, forming mottles, nodules and metanodules. When, at the top of profiles, goethite and sometimes gibbsite develop at the expense of hematite and kaolinite, protopisolitic and pisolitic dismantling facies are formed. Ferricretes, in which hematite and kaolinite form concretions, are widespread and are the most common iron accumulations.

Latosols are soft lateritic covers with a microglaebular structure. Red latosols, like ferricretes, are essentially formed by an association of hematite and kaolinite, but with larger proportions of goethite and with the presence of gibbsite.

Lateritic bauxites are concentrations of aluminium with which iron is very often associated. Four major types of lateritic bauxites: protobauxites, orthobauxites, metabauxites and cryptobauxites are defined as a function of the nature of iron and aluminium minerals as well as their relative distributions in profiles.

Protobauxites are lateritic soils where gibbsite and goethite form together under very humid climates. Orthobauxites are allites or alferrites, rich in gibbsite and red in colour, which do not exhibit a concretionary structure. Iron may be concentrated in hard caps called conakrytes and located close to the top of the bauxitic profiles. Conakrytes are reticular and non nodular ferrites or ferrallites in which hematite and goethite dominate and where gibbsite could be present in small proportions. The presence of kaolinite at the bottom of the profiles is not necessary. Metabauxites are boehmitic and show a concretionary or pisolitic structure; iron is dissociated from aluminium and is frequently concentrated as hematite in a kaolinitic ferricrete located at the bottom of the bauxitic profile. Kaolinite always appears at the bottom of metabauxite profiles and less frequently at the base of orthobauxites. In cryptobauxites, kaolinite is abundant at the top and at the bottom of the profiles so that the gibbsitic layer is embedded between two kaolinitic horizons.

This petrological and geochemical classification of laterites is based on reactions of hydration–dehydration and of silication–desilication regulated by temperature, water activity and chemical composition of the parent material. Lateritic bauxites, ferricretes and latosols are witnesses of the succession of paleoclimates throughout the last 150 million years, since the Atlantic opening.

Keywords: laterites, ferricretes, latosols, conakrytes, bauxites, hematite, goethite, kaolinite, gibbsite, boehmite

INTRODUCTION

Bauxites (massive or pisolitic, and often indurated), conakrytes (massive or reticulated and often indurated), latosols (soft and microglaebular) and ferricretes (nodular and always indurated) are lateritic covers, widely distributed in North and South America, in West, Central and East Africa, as well as in Australia, India and South East Asia. These laterites form under tropical climates depending on rainfall, temperature, length of the dry season and on the nature of the parent material. Their geographic distribution is larger than the latitudinal zones of climates under which they normally form or develop. Almost all of them are very old: some are fossil, others are still active, but most of them are polygenic.

Some bauxites formed under humid conditions and later evolving under a drier climate, may generate ferricretes localised at the bottom of profiles, while ferricretes formed under seasonally contrasted climate, later evolving under wetter conditions may generate a new bauxitic horizon within a soft kaolinic latosol (Tardy *et al.*, 1991; Tardy and Roquin, 1992; Tardy, 1993).

CLASSIFICATION OF IRON-RICH LATERITES

Tardy (1993) distinguishes two mechanisms of iron accumulation: concretion and excretion as well as four kinds of iron-rich lateritic formations: (i) mottled horizon and nodular ferricretes, (ii) microglaebular latosol, (iii) conakrytes of massive structures and (iv) plinthites and petroplinthites.

Ferricretes: nodular iron-rich accumulations

Ferricretes or 'cuirasses ferrugineuses' *stricto sensu* are indurated iron concentrations, showing generally a noticeable nodulation. The words ferricrete, calcrete and silcrete are formed like concretion with 'the formant crete' which etymologically comes from Latin *con-crescere* signifying to cement or to grow together. Although these features may exhibit a concentric structure (Pettijohn, 1957) the definition of concretions does not include that they are concentric as proposed by Brewer (1964) but are only indurated or cemented accumulations. Concretion also designates the mechanism of cementation and induration, by centripetal accumulation of material, in pores of small size (Tardy, 1993). In ferricretes, the mechanism of concretion leads to the formation of indurated nodules by accumulation of hematite in the very fine porosity developed by kaolinite crystal assemblages.

In a sequence of ferricrete development from mottles (diffuse accumulations) to subnodules (nodules with diffuse edges), nodules (with distinct edges), and to metanodules (anastomosed), iron content increases, quartz content decreases drastically, while kaolinite content decreases slowly or even increases moderately. In mottles goethite dominates hematite, but in well developed nodules the contrary is observed. The ratio hematite/(hematite + goethite) increases from the mottled zone to the ferricrete zone.

Concretion and nodulation, the fundamental process of ferricrete formation, is based on the association of hematite and finely crystallised kaolinite.

Compared to hematite (Fe_2O_3), goethite is hydrated ($Fe_2O_3.H_2O$). Gibbsite ($Al_2O_3.3H_2O$) is more hydrated than kaolinite ($SiO_2.Al_2O_3.2H_2O$). The stability of hematite–kaolinite nodules is ensured as long as hematite and kaolinite are stable, i.e. they are not rehydrated or desilicated.

Tardy (1993) has shown that this association of dehydrated or poorly hydrated minerals is very stable and develops under tropical climates with a long dry season. This paragenesis hematite–kaolinite, when previously formed under contrasted tropical climates, is even stabilised in more arid conditions. In contrast, nodules of hematite and kaolinite are destabilised in humid tropical conditions, particularly under the great equatorial forest (Beauvais and Tardy, 1991).

Latosol: a microglaebular iron-rich laterite

Beauvais (1991) and Beauvais and Tardy (1991) have shown that, under a humid climate, the transformation of a ferricrete into a microglaebular latosol corresponds to the transformation of a part of kaolinite into gibbsite by desilication and hydration, and to the transformation of hematite into goethite by hydration. During this process, the size of nodules is reduced and they are transformed into microglaebules.

Tardy and Roquin (1992) and Tardy (1993) have delineated the climatic limits of formation of latosols and ferricrete by taking into account their distribution in both Brazil and Africa.

Finally, ferricretes form under tropical climates which are warm, humid and seasonally contrasted ($T \simeq 25°C$; $1100 < P < 1700$ mm y^{-1}).

An increase in humidity to above 1700 mm y^{-1} or a decrease of temperature to below 25°C act in favour of the dismantling of ferricretes and their transformation into latosols (Tardy and Roquin, 1992).

Conakrytes: massive and non-nodular iron accumulations

There are non aluminous iron accumulations which develop from non aluminous parent rocks, such as dunites, similar to those described by Bonifas (1959), in Conakry (Guinea). They are widely distributed lateritic products formed by weathering of ultramafic rocks and are characterised by massive or crystalliplasmic structures and the absence of concretions or nodules. Consequently they cannot be called ferricretes even if indurated. They were called *conakrytes* (Tardy, 1993)

Orthobauxitic profiles (discussed later) are very often capped by ferruginous hardcaps (Grubb, 1971) which were improperly named laterites by Balasubramanian *et al.* (1987). As in Mali (Tardy, 1993), these ferruginous horizons are often gibbsitic and of massive structure and, consequently, do not exhibit concretions. The absence of concretion is due to the fact that under very humid climates gibbsite forms instead of kaolinite. Hardcaps are not ferricretes in the sense of Nahon (1976) but aluminous conakrytes associated with ferruginous bauxites.

Plinthite: a cutanic and reticular iron-rich laterite?

Camargo *et al.* (1988), in the Brazilian soil classification, referring to the FAO soil classification (FAO-UNESCO, 1975), and numerous other researchers describe a plinthite as an iron accumulation showing laminar, reticular or polygonal organisation. An iron accumulation principally characterised by mottles or nodules, which result from concretion, must be classified as a mottled horizon (soft material) or a ferricrete (hardened material).

Consequently, if the reading of the term reticular is correct, an iron accumulation characterised by iron-rich reticular cutans more abundant than nodules may be classified as a plinthite (soft material) or petroplinthite (hardened material). The first should correspond to a gley, the second should correspond to a pseudo-gley.

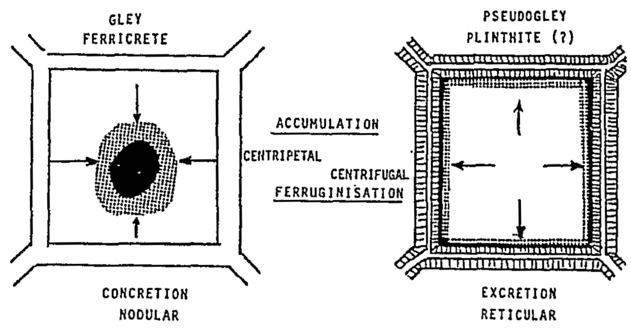

Fig. 1 Concretion (mottle and nodule formation) versus excretion (cutan formation): two processes of iron accumulation which may allow, if acceptable, the distinction of ferricretes from plinthites. (from Tardy, 1993).

Tardy (1993) has shown that what he called *excretion* and *incrustation*, which appear as cutanic accumulations, have to be clearly distinguished and separated from *concretions*. A cutan of excretion results from a centrifugal transfer of the argillaceous matrix with a porosity of small size towards the voids and the porosity of large size. A cutan of incrustation results in a transfer of matter which goes from voids and the porosity of large size towards the soil matrix. *Excretion* and *concretion* are opposite with respect to features (cutan versus nodule) and to processes (centrifugal versus centripetal). *Excretion* and *incrustation* are similar with respect to features (cutans in both cases) but are of opposite polarity (centrifugal versus centripetal). *Incrustation* and *concretion* are opposite with respect to feature (cutan versus nodule) but similar with respect to the polarity of processes (centripetal towards the porosity of fine size). The process of excretion corresponds to the leaching of iron from kaolinitic domains and to the cutanic accumulation of hematite in the voids. Excretion is clearly distinguished from concretion which corresponds to a leaching in domains close to the voids and an accumulation of hematite in domains rich in kaolinite.

Obviously this distinction was not taken into consideration so that plinthite and ferricrete are both indistinctly used to designate all kinds of iron accumulations. It is suggested here that plinthites and petroplinthites, defined as iron cutanic and reticular accumulations resulting from a process of excretion, have to be clearly separated from mottled horizons and ferricretes which are iron accumulations resulting from a process of concretion (Fig. 1). Climates of development are distinct. Mechanisms of formation are different.

CLASSIFICATION OF LATERITIC BAUXITES

The bauxitisation of very thick lateritic profiles is slow, requiring millions to tens of millions of years to form. This is the reason why bauxitic profiles have been evolving under different types of climatic and morphological situations which do not necessarily correspond to their conditions of formation.

Protobauxites

Protobauxite is the name of a gibbsitic soil that could be considered as the precursor of a lateritic bauxite. It is rather difficult to determine with precision the time required for transformation and what is the type of soil which could be the precursor of thick bauxitic profiles. Tardy (1993) admitted that among the different types of oxisols (sols ferrallitiques, in the French classification) the most sensitive to bauxitisation are the red or the yellow oxisols in which gibbsite, goethite and hematite dominate and where kaolinite and quartz are, at least originally, subsidiary (Sieffermann, 1973).

Orthobauxites

The prefix *ortho* in Greek means normal. Orthobauxites are products of evolution of gibbsitic protobauxites, developed under an annual rainfall greater than 1700 mm y^{-1} (Tardy, 1993).

A typical orthobauxitic profile is made of three major horizons (Valeton, 1972, 1981; Aleva, 1979, 1981, 1982, 1989; Bardossy, 1989; Bardossy and Aleva, 1990). From the top to the bottom one finds:

- a ferruginous, hematitic and gibbsitic horizon, red in colour, located close to the surface;
- a bauxitic horizon, less coloured, less ferruginous and more aluminous, with gibbsite and hematite;
- an argillaceous horizon, rich in kaolinite, poorly ferruginous and red-yellow in colour.

Typical orthobauxitic profiles are those of Mounts Bakhuis, Surinam (Aleva, 1981), Jarrahdale in the Darling Range, Australia (Grubb, 1971), Mount Tato at Lakota in the Ivory Coast, Africa (Boulangé, 1983, 1984) and some profiles of Famansa in Mali, Africa (Tardy, 1993), which are of Cretaceous age (Michel, 1973).

There are two types of bauxites in Famansa: orthobauxites and metabauxites. The orthobauxites are homogeneously red, and do not exhibit nodules, concretions or pisolites. Over thicknesses of about 10 m they are constituted of gibbsite, hematite and goethite. From the bottom to the top of profiles, typical orthobauxites show an increase in iron (goethite and hematite) versus aluminium (gibbsite) content, an increase in the hematite/goethite ratio and a decrease in the content of quartz and kaolinite (Tardy, 1993).

An orthobauxite is dominantly gibbsitic in the thick intermediate horizon and does not show boehmite, pisolites or concretions. It is normally capped by a conakryte when developed from a ferruginous parent rock.

There are several orthobauxitic profiles which do not exhibit a kaolinitic layer at the base and where bauxite develops down to the contact with the unaltered parent rock. The volume and the architecture of the parent rock are preserved and that is the reason why Boulangé *et al.* (1973, 1975) and Boulangé (1984) call these formations isalteritic bauxites.

Cryptobauxites

In Amazonia, bauxites are widespread. Lucas *et al.* (1986) and Lucas (1989) have presented an interesting synthesis concerning the ore deposits of Juriti and Trombetas. The parent rocks are sandstones and argillites of Alter-do-Chão from the later Cretaceous or the early Tertiary (Daemon, 1975). All bauxitic profiles are capped by an argillaceous horizon, very rich in kaolinite and poor in quartz, called Clays of Belterra and considered by Sombroek (1966) and Tricart (1978) as a Quaternary sedimentary lacustrine formation; by Grubb (1979), Kotschoubey and Truckenbrodt (1981) as a Pliocene lacustrine or desertic deposit; and finally by Aleva (1981, 1989) as a sedimentary cover. Chauvel *et al.* (1982) and Lucas *et al.* (1984) first called attention to a pedogenetic origin, while Tardy (1993) proposed that the pedogenetic phase takes place in a biogenic formation. The peculiarity of this type of bauxite comes from the fact that a gibbsitic horizon is interbedded between two kaolinite-rich horizons.

It is also interesting to remark that hematite is associated with gibbsite in the bauxitic horizon while goethite is the iron mineral dominant in the superficial layer. We agree with Lucas (1989) that bauxites of Amazonia are polygenic. They are similar to gibbsitic soils of Cameroon such as those described by Muller (1987). Both were considered by Tardy (1993) to be ancient ferricretes, formed under seasonally contrasted tropical climates and later dismantled under a more humid tropical climate. Gibbsite forms in place of the ancient ferricrete, and continues to develop in situ, close to the water table (Lucas, 1989) but below a thick kaolinic soft horizon, so that the bauxite layer is called cryptobauxite. This peculiar distribution implies a strong necessity of supplying silica from the lower to the upper part of the profile. Several biological processes can be responsible for that: termites (Truckenbrodt *et al.*, 1991) or phytolites (Lucas *et al.*, 1993). Cryptobauxites are common in equatorial forests and, if really polygenic, characterise a paleoclimatic succession which has been moving from arid to humid. The opposite is observed for the metabauxite evolution.

Metabauxites

Metabauxites are orthobauxites, initially formed under a tropical humid climate and later transformed under warmer and drier climates. *Meta* in Greek means which comes later. Metabauxites are diagenetised bauxites (Tardy, 1993).

Typical metabauxite profiles

Some of the most typical profiles that we can classify as metabauxites, are those of Weipa and Pera Head, in the Cape York Peninsula, N.E. Australia. They were described by Loughnan and Bayliss (1961) and Loughnan (1969). Over a thickness of 10 m, a quartz–argillaceous sandstone is transformed into an aluminium-rich bauxite. From the bottom to the top of the profile, quartz and kaolinite, always present, diminish while gibbsite and boehmite increase. In the lower part, goethite dominates while in the higher part, hematite becomes the dominant iron mineral.

The metabauxite profile of Famansa in South Mali was described by Tardy (1993). This so-called white bauxite profile exhibits, over 10 m of thickness, an increase in aluminium, gibbsite and boehmite and a decrease in silicon towards the profile surface. The three ratios boehmite/(boehmite + gibbsite), hematite/(hematite + goethite) and gibbsite/(gibbsite + kaolinite) rise constantly from the bottom to the top of the profile. In this profile, iron does not accumulate in the superficial horizon but at depth, between 6 and 8 m, forming a typical kaolinite–hematite rich nodular ferricrete.

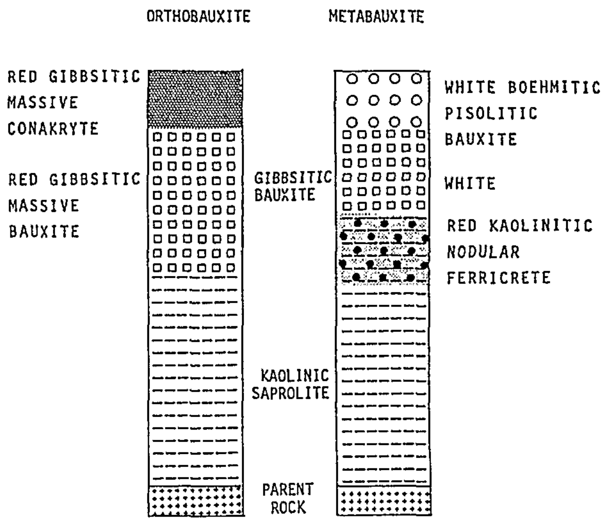

Fig. 2 Schematic distribution of boehmite, gibbsite, kaolinite and hematite in conakrytes associated with orthobauxites on one hand and in ferricretes associated with metabauxites on the other hand (from Tardy and Roquin, 1992; Tardy, 1993).

Metabauxites are deferruginised at the top but ferruginised at the bottom of profiles. The massive gibbsitic structure is replaced by a boehmitic, pisolitic structure. In orthobauxites, iron in hematite and aluminium in gibbsite are associated at the top of the profile forming conakrytes of massive structure. In metabauxites, at the surface of profiles, iron and aluminium in boehmitic pisolites separate, while in the ferricrete located at the bottom, iron in fine grained hematite and aluminium in kaolinite are again associated.

Regional metabauxitisation

Balkay and Bardossy (1967) first pointed out that the amounts of boehmite in bauxites of Western Africa, increase from the south to the north.

Seven regions were distinguished by Bourdeau (1991), who studied 3750 analyses of samples collected by Pechiney-Sarepa

Table 1 Elements of classification of iron and aluminium laterites

Name	Structure	Al (contents)	Fe	Hematite (size)	Goethite	Gibbsite (contents)	Boehmite	Kaolinite
Conakryte	crystalliplasmic	poor	abundant	large	present	present	absent	absent
Ferricrete	nodular	moderate	abundant	very small	present	possible	absent	abundant
Orthobauxite	massive	abundant	moderate	large	present	abundant	absent	absent
Metabauxite	pisolitic	very rich	poor	very small	absent	present	abundant	present
Latosols	microglaebular	medium	medium	small	moderate	frequent	absent	abundant

Note that hematite is always present but in different sizes and gibbsite is always present but in different proportions

Table 2 Geochemical and mineralogical classification of laterites

Name	Geochemical process	Mineral constituents	Geochemical composition
Conakryte[1]	hydro-ferrallite	goethite, hematite, gibbsite	$Fe_2O_3.H_2O.Al_2O_3$
Conakryte[2]	ferrite	hematite, goethite	$Fe_2O_3.H_2O$
Ferricrete	xero-fersiallite	hematite, kaolinite	$Fe_2O_3.SiO_2.Al_2O_3.H_2O$
Orthobauxite	hydro-alferrite	gibbsite, goethite, hematite	$H_2O.Al_2O_3.Fe_2O_3$
Metabauxite	xero-allite	boehmite, hematite	$Al_2O_3.Fe_2O_3$
Red latosol	xero-sialferrite	kaolinite, hematite, goethite	$SiO_2.Al_2O_3.H_2O.Fe_2O_3$
Yellow latosol	hydro-sialferrite	goethite, kaolinite, gibbsite	$H_2O.Al_2O_3.SiO_2.Fe_2O_3$
Podzol	sillite	quartz	SiO_2

[1] conakrytes on aluminous rocks, [2] conakrytes on ultramafic rocks

in bauxites of Guinea and Mali: (I) Fouta Djalon in Guinea, (II) Balea, North of Guinea, (III) Bamako-West in South Mali, (IV) Falea, (V) Kenieba in South-West Mali, (VI) Koulikoro, West Mali and (VII) Bafoulabe North-West Mali. In each region, the upper or superficial and the lower horizon of the profile, were distinguished.

It is clear that from the south (humid) to the north (dry and hot) i.e. from the humid Guinea to the Sahara

water content diminishes;

- iron content decreases in the superficial horizon;
- in the deep horizon, iron content increases and aluminium decreases;
- gibbsite and goethite contents diminish, while hematite and boehmite increase;
- kaolinite content increases;
- the contrast between ratios: Al_2O_3/Fe_2O_3 in the upper horizon versus Al_2O_3/Fe_2O_3 in the lower horizon increases significantly.

From the south to the north, bauxites dehydrate, more so in the upper than in the lower horizon. Accompanying the dehydration process, a migration of iron proceeds from the top (conakryte) to the bottom of the profile (ferricrete) (Tardy, 1993) (Fig. 2).

CONCLUSION

Tables 1–3 summarise the elements of classification of iron-rich and aluminium-rich lateritic formations. They are conakrytes, ferricretes, orthobauxites, metabauxites and latosols. As well as the nature of the parent rock, climatic and paleoclimatic influences are major factors controlling the nature of laterites.

Aluminous conakrytes and orthobauxites are associated in humid conditions. Ferricretes form under seasonally contrasted climates. Ferricretes and metabauxites can be associated in semi-arid or arid conditions because metabauxites are ancient orthobauxites formed under humid climates and further dehydrated and deferruginised.

Hematite is less hydrated than goethite:

$$Fe_2O_3 + H_2O \rightarrow 2FeO(OH) \quad (1)$$

Boehmite is less hydrated than gibbsite:

$$AlO(OH) + H_2O \rightarrow Al(OH)_3 \quad (2)$$

and finally, kaolinite contains more Si but is less hydrated than gibbsite:

$$Al_2Si_2O_5(OH)_4 + 5H_2O \rightarrow 2Al(OH)_3 + 2H_4SiO_4 \quad (3)$$

Reactions of hydration–dehydration and silication–desilication are the processes of laterite climatic formation and paleoclimatic evolution. Dehydration favours concretion and formation of nodules while hydration favours excretion and development of crystalliplasmic structures. In ferricretes hydration of hematite into goethite favours the dismantling of previously formed nodules. In contrast, hydration of bauxites, favours the induration of crystalliplasmas of gibbsite. Dehydration works in the

Table 3 Climatic conditions (H: humidity; T: temperature) and paleoclimatic evolution (H_1–H_2; T_1–T_2) for controlling the laterite evolution

		Parameter		Paleoclimatic	Parameters			
	Tropical climate	H	T	evolution	H_1	H_2	T_1	T_2
Conakryte(1)	humid	medium	high	constantly humid tropical	›			›
Conakryte(2)	undifferent.	—	—	undifferent.	—			—
Ferricrete	tropical contrasted	high	medium	constantly contrasted	—			—
Latosol	cool humid	high	medium	from contrasted to humid		/	\	
Orthobauxite	humid	high	medium	constantly humid	›			›
Metabauxite	arid	low	very high	from humid to arid		\	/	
Cryptobauxite	humid	high	medium	from arid to humid		/	\	

[1] from ferrialuminous rocks; [2] from ultramafic rocks.
H_1, H_2: humidity stage 1 or 2; T_1, T_2: temperature stage 1 or 2.

direction of aggradation and induration. Hydration works in the direction of degradation and dismantling (Tardy, 1993).

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