

APPENDIX H: SOIL AND LAND CAPABILITY STUDY



Our Ref: MEE.LHP.S.09.03.020
Your Ref:

23rd July 2009

Metago Environmental Engineers (Pty) Ltd
P.O. Box 1596
CRAMERVIEW
2060

Tel +27 (0)11 467 0945, Fax. +27 (0)11 467 0978, Cell. +27 (0)84 200 1657
E-mail: Brandon@metago.co.za

Att: Mr. Brandon Stobart

**Re: Langer Heinrich Uranium Expansion Project
Specialist Soils and Land capability Assessment**

Dear Sir,

In line with the Terms of Reference supplied under your project number L016-01 (Order No. 1203 dated 16th March 2009), and discussions had with the Metago team regarding the soils and land capability assessments required and proposed for the Langer Heinrich Uranium expansion project, the following draft report detailing the findings of the site investigation, and the results is tabled for your comment.

Should you require any additional information in this regard, please do not hesitate to contact us.

Yours sincerely
Earth Science Solutions (Pty) Ltd.

A handwritten signature in black ink, appearing to read 'Ian Jones', is written over a horizontal line.

Ian Jones
Director

EARTH SCIENCE AND ENVIRONMENTAL CONSULTANTS

REG No. 2005/021338/07

Nelspruit Office:
Tel: 013-753 2746, Fax: 013-752 2565
E-mail: ess@earthscience.co.za
PO Box 26264, Steiltes, Nelspruit, 1200

Middelburg Office:
Tel: 013- 243 5864, Fax: 013-243 5866
E-mail: ian@earthscience.co.za

Langer Heinrich Uranium Expansion Project

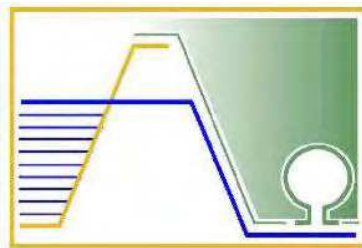
SPECIALIST SOILS AND LAND CAPABILITY STUDIES

Final Report

Compiled By



For



metago
Environmental Engineers (Pty) Ltd

July 2009

CLIENT: Metago Environmental Engineers (Pty) Ltd
P.O. Box 1596
CRAMERVIEW
2060

Cnr. Roos and Macbeth Streets
FOURWAYS
Johannesburg
South Africa

Tel +27 (0)11 467 0945
Fax. +27 (0)11 467 0978
Cell. +27 (0)84 200 1657
E-mail: fiona@metago.co.za

Proposal Number: MEE.LHP.S.09.03.020

Client: Langer Heinrich Uranium Expansion Project

Attention: Fiona Parkin/Brandon Stobart

DOCUMENT ISSUE STATUS

Report/Proposal Name	Langer Hienrich Project			
Report/Proposal Number	MEE.LHP.S.09.03.020			
Report Status	Final Report			
Carried Out By	Earth Science Solutions (Pty) Ltd			
Commissioned By	Metago Environmental Engineers			
Copyright	ESS (Pty) Ltd.			
Title	Name	Capacity	Signature	Date
Author	Ian Jones	Director		20 th July 2009
Project Director	Brandon Stobart	EAP		
Technical Review	Fiona Parkin	Environmental Scientist		

* This report is not to be used for contractual or engineering purposes unless permissions are obtained from the authors.

EXECUTIVE SUMMARY

Soils and Land Capability Assessment:

The proposed Langer Heinrich Uranium expansion operations are planned as opencast mining operations, the majority of the mining planned to exploit the colluvial and alluvial gravels and sediments that contain the natural resource within the Gawib River valley at Langer Heinrich. Mining will follow a sequence of truck and shovel operations using bench mining, with backfill of the open pit structures with overburden and the tailings by-product on completion of the extraction process (mining). These areas will be engineered to as close a possible the original topographic land form, and will be rehabilitated with the saved/stockpiled soil coverer and vegetated to as close as possible their original state.

The main components of the expansion project include: an increase in the rate of mining and expansion of the open pit operations to the east, a new satellite mine workshop, the expansion of the existing processing plant, a new satellite crushing plant and concentrator section, a heap leach pad, modifications to tailings management and additional support infrastructure and services. In addition, there will be associated facilities and operations servicing the processing facilities including an expansion to the clean and dirty water management facilities, dust management and monitoring around areas of soil disturbance and rehabilitation sites.

The study was undertaken on two differing scales and intensity of investigation, with more detail being paid to the proposed areas of new infrastructure development (were delineated at the time of study), and a less intense coverage of the general mining right area and areas that are proposed for mining (river valley). The pipeline route was mapped as an addition to the original scope of work, with a regional assessment of the mining right area.

Of importance to the development of any project is the understanding of the sustainability of the project, and the degree to which the impacts of the operation or development can be mitigated. An understanding of the baseline conditions is paramount to any operation if rehabilitation is to meet the minimum criteria and obtain a stable and stand alone state at closure. The findings of the baseline study will be used to not only obtain an understanding of what will need to be removed and what will be stockpiled and saved during the construction and operational phases of the project, but is essential in formulating a plan for the reinstatement of the materials in closing the project. This is specifically important to the Langer Heinrich situation due to the fine balance in the ecological systems that prevail in the area.

Taking this into account, and with an understanding of the impacts that this overall mining plan could have on the environment, it was imperative that a full understanding of the environment that is to be disturbed and affected was obtained prior to the implementation of any mining or mining related activities taking place. In addition to the mining to be undertaken, there will be a number of surface features/structures that will impact on the environment (both physical and social), which will need to be assessed and mitigated.

Apart from the more obvious environmental studies (Fauna and Flora, Surface Water etc.) that need to be undertaken prior to the implementation of a new development, it has become increasingly apparent that the soils need to be investigated in detail if a comprehensive base line of information is to be available for future reference and the materials are to be used in a sustainable manner through the operational phase and into rehabilitation. In compliance with the local environmental legislation (still in draft), a comprehensive pedological investigation at various scales (depending on the degree of disturbance to be implemented), coupled with an interpretation, and understanding of the land capability for the area to be disturbed has been undertaken as part of the overall Environmental Management Plan, and Environmental Management Programme.

Generally the survey area is characterised by moderately shallow to shallow and highly sensitive alluvial and colluvial derived soils which are unique to the environment (desert) and will require careful management. The current land capability is rated as wilderness or very low intensity grazing land on the S.A. Chamber of Mines Guidelines (1991), with conservation/wilderness the preferred land use option for the area. The unique climatic conditions (low rainfall, high evaporation and coastal fogs that reach inland as far as Langer Heinrich) and resultant pedogenetic characteristics that result from these interactions are all important to the ecological cycle and sustainability of the eco-systems. Of great importance to the area is the existence of "evaporites" both as surface capping and as restrictive horizons within the pedological horizon and/or as the "C" horizon at the base of the soil profile. These features have been highlighted as important to the pre-mining baseline conditions, and will be analysed in more detail as part of the impact and management requirements.

Successful rehabilitation of these sensitive soils and underlying materials will require significant management and engineering input if they are to sustainably support the sensitive vegetative cover and ecosystems that typify the area at present. It is important that the findings of this specialist study are read in conjunction with the biodiversity studies and ecological baseline assessments if the long term "End Land Use" is to be understood, and a viable rehabilitation plan developed.

A summary of the findings of the soil study for the Langer Heinrich Uranium Mine expansion are as follows:

The major soil types encountered include those of the orthic phase Augrabies, Prieska, Clovelly, Oakleaf, Dundee, Hutton, Mispah and Glenrosa.

The soils range from very low intensity (poor quality) grazing lands with no significant economic potential, to highly sensitive wilderness and conservation status lands.

The soils are associated with an evaporite layer (calcrete) either at surface and/or at a moderately shallow depth. These layers are significant to the ecological balance of the desert environment.

Physical Characteristics

- ❖ Where present, the evaporite crusting on surface is extremely thin and appears to be associated with the accumulation of calcium salts due to the high evaporation status;
- ❖ Topsoil clay percentages range from as low as 2% to more than 18% depending on the host/parent geology from which they are derived, and their position in the landscape/topography;
- ❖ Subsoil clays that range from 10% to 25%;
- ❖ Moderate to high in-situ permeability rates on the more clay rich loams and sandy clay loams;
- ❖ A significantly thick and impermeable calcrete (evaporite) as the "C" horizon to many of the pedological profiles mapped;
- ❖ Moderate to good intake (infiltration) rates, depending on the type of clay present;
- ❖ Moderate to poor water holding capacities, and
- ❖ Poor to very poor and unsuitable agricultural potential ratings (nutrient status).

The physical characteristics are highly influenced by the parent materials from which the soils are derived, as well as their relative position in the topography, all be it that a significant percentage of the soils that are likely to be disturbed are associated with colluvial and/or alluvial deposits within the alluvial floodplain, all of which are relatively young in pedological age, and are the product of the various geologies that are being eroded upslope.

The in-situ soils that occur on the desert plains are very sensitive to wind and water erosion, and have a significantly shallower rooting depth on average than the alluvial soils, with a large proportion of the site being less than 400mm in depth, and large areas of outcropping geology outside of the alluvial valleys.

The structure of the soils varies from very loose and single grained structure for the majority of the alluvial sediments and colluvial derived materials, to apedel and in isolated instances weak crumbly structures on the more silty loams and more clay rich soils that form the in-situ derived materials associated with the host rock and desert plains.

The extremely dry environment and resultant formation of evaporates at shallow depths has resulted in the accumulation of salts and associated clay minerals as inhibiting and restrictive layers on surface (desert plains) and at the base of the soil profile. In addition, the highly variable size fraction of the materials that make up the soil profile (silt and fine sand inter-layered and bedded with pebbles and cobble size material) is significant in the pedogenesis and resultant variation in soil forms mapped. The Prieska and Augrabies Forms are symptomatic of the arid environment with extremely high evaporation rates and low rainfall.

The low organic carbon, moderately low to very low clay contents and relatively steep gradients associated with the mountain ranges and undulating terrain that makes up the Langer Heinrich area are in part responsible for the high erosion indices, while the geological structure and chemical composition of the parent materials result in a complex of transported materials that form the colluvial and alluvial materials associated with the streams and rivers that make up the Gawib River Catchment. While compaction is not of great concern in the natural environment, it is of consequence to the successful implementation of any rehabilitation plan, and has been assessed as part of the baseline study. The variable grain size of the materials will, when mixed and/or disturbed, result in compaction. However, the inclusion of the larger fraction (cobbles and boulders) will cause problems with the engineering of compacted layers.

The moderately complex nature of the geology (physical and chemical) of the area, the attitude (dip and strike) of the materials the severe climatic conditions (moderate to strong winds and freeze and thaw) associated with the desert climate in combination with the structural deformation (folding of the rock formations) all play a significant role in the soils produced and the colluvial/alluvial materials that occur within the Swakob River and its major tributaries, and which contain the minable product. The grain size variation and distribution (cycles of deposition) are important factors noted in the baseline study that will play a significant role in any rehabilitation planning for the future.

Storage of the relatively more nutrient rich "topsoil" and utilizable subsoil will be imperative if any rehabilitation is to be successful, while the "calcrete" (evaporate) layer that has to all intents and purposes formed the underlying impermeable layer and the source of shallow water within the streams and river sands will need to be recognised as a fundamental contributor to the success of the ecological balance in the area (accessible water stored in the sands). The occurrence and formation of a very thin (<5mm) surface layer or crusting in some places is not well understood, and its function within the ecological and biophysical sustainability, is a debate within the specialist fraternity.

Chemical Characteristics

The chemistry of the alluvial soils is typical of the weathered product of the surrounding geology and upstream environs (Feldspathic quartzites, mica schists, calc silicates and red granites), with a mixture of alluvial derived materials that are part of the active stream environment, with high levels of movement of suspended solids as well as soluble materials within the profile, while the colluvial materials are areas of accumulation of clays and concentrations of nutrient

rich materials. In general, the river sediments (alluvial material) returned lower than average nutrient levels for the area in general, with slightly better reserves of the basic growth requirements associated with the colluvial and in-situ materials. The soils are characteristically:

- ❖ Slightly alkaline in pH, with a range of between 8.10 and 8.75;
- ❖ Higher than average amounts of calcium and sodium;
- ❖ Lower than required quantities of magnesium and zinc, copper, potassium and aluminium;
- ❖ Adequate reserves of phosphorus;
- ❖ Extremely low clay contents (<6%), and
- ❖ Very low organic carbon (0.07 – 0.17 C%)

As a result, these soils require significant amounts of some nutrients as additives/input if they are to be used as a growing medium (rehabilitation). Grazing of wild game on a very low stocking density could be considered, and is the primary natural activity of the area in its natural state.

The impact of development on the soils and the resultant change in the land capability is highly variable due to the very unique differences associated with the riverine deposits (alluvial) the colluvial derived materials, and the in-situ soils.

Of the total mining/mineral right area (Red boarder), only a small proportion of the area will be impacted by the proposed development, with significant areas of the Gawib River and its tributaries being targeted for open cast mining, while much smaller areas in close proximity to the mining have been ear marked for the expansion to the processing facilities (Heap Leach Pads administrative facilities, workshops, the concentrator and RoM Stockpiles), a large Tailings Storage Facility and associated infrastructure.

The open cast nature of the mining operation, and the sensitive environment in which it is to take place will require extensive and high level management input if the original characteristics are to be engineered at rehabilitation.

The impact on the in-situ soils is likely to be confined to the construction of the permanent TSF, modules of the extension to the processing and concentrator facilities, and the stockpiling of run of mine product, and is generally confined to disturbance of the shallow to very shallow and in many instances the areas of outcrop that occupy the much steeper terrain. These soils are sensitive to erosion and compaction, and will need to be well managed. However, the extremely shallow nature of the utilizable soil (in most cases) renders these soils easier to work and store, and the impact on the land capability is less.

In contrast, the colluvial and alluvial derived soils that make up the river and stream banks and river channel materials respectively are far more sensitive to disturbance, with some major challenges associated with re-instatement and replacement of the utilizable materials as a result. This disturbance will impact and affect the overall ecology in the long term. The highly variable size fractions within the soil materials and the layered nature of these sediments combined with the presence of a prominent calcrete (Calcium Carbonate) layer at the base of the soil profile ("C" Horizon) which forms the restriction to vertical infiltration of water below the sands and gravels, all make for a complex of natural conditions that are going to be extremely difficult to replicate at closure.

The resultant loss of sub surface water within the gravels 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 of some important nutrients within the top soils will require that good handling and storage of the resource is managed, with the concept of "**utilizable soil**" storage being adapted as a basic management tool.

The robust nature of most of the vegetation is an advantage to any rehabilitation venture, however, the need for water and nutrients cannot be over emphasised, and management and engineering of the re-instated materials will be difficult but necessary for a successful rehabilitation plan.

TABLE OF CONTENTS

GLOSSARY OF TERMS	1
1. INTRODUCTION AND TERMS OF REFERENCE	3
2. DESCRIPTION OF THE PRE-CONSTRUCTION ENVIRONMENT	8
2.1 Soils	8
2.1.1 Data Collection	8
2.1.2 Description	16
2.1.3 Soil Chemical and Physical Characteristics	19
2.1.4 Soil Erosion and Compaction	24
2.2 Pre-Construction Land Capability	26
2.2.1 Data Collection	26
2.2.2 Description	26
3 Alternatives Assessment	32
4. IMPACT ASSESSMENT	33
4.1 Soils	37
4.1.1 Construction Phase	37
4.1.2 Operational Phase	39
4.1.3 Decommissioning & Closure Phase	41
5. ENVIRONMENTAL MANAGEMENT PLAN	43
5.1 Construction Phase	46
5.2 Operational Phase	48
5.3 Decommissioning and Closure	50
6. CONCLUSIONS	53
LIST OF REFERENCES	54

LIST OF FIGURES

Figure 1a	Locality Plan	5
Figure 1b	Proposed Mining Plan – Option A	6
Figure 1c	Proposed Mining Plan – Option B	7
Figure 2	Regional Geological Map	10
Figure 2.1.1a	Soil Polygon Map – Mining Lease Area West	13
Figure 2.1.1b	Soil Polygon Map – Mining Lease Area East	14
Figure 2.1.1c	Soil Polygon Map – Pipeline Route	15
Figure 2.2a	Land Capability Plan – Mining Lease Area - West	29
Figure 2.2b	Land Capability Plan – Mining Lease Area – East	30
Figure 2.2c	Land Capability Plan – Pipeline Route	31
Figure 5a	Proposed Stripping Plan (WEST)	44
Figure 5b	Proposed Stripping Plan (EAST)	45

LIST OF TABLES

Table 2.1.1	Typical Arrangement of Master Horizons in Soil Profile	12
Table 2.1.2a	Soil Coverage – Mining Lease Area	18
Table 2.1.2b	Soil Coverage – Pipeline Route	19
Table 2.1.3.1	Analytical Soils Results	20
Table 2.1.4	Erodibility of Differing Soil Forms	25
Table 2.2.1	Criteria for Pre-Construction Land Capability (S.A. Chamber of Mines 1991)	26
Table 2.2.2.1a	Land Capability – Mining and Infrastructure	27
Table 2.2.2.1b	Land Capability – Pipeline Route	27
Table 4a	Existing Mining and Related Activities at Langer Heinrich	33
Table 4b	Criteria for Assessing Impacts	36

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.

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 clay skin, clay film, argillan.

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.

Fertilizer: 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 60% of the sand fraction.

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

Hardpan: A massive material enriched with and strongly cemented by sesquioxides, chiefly iron oxides (known as ferricrete, diagnostic hard plinthite, ironpan, ngubane, oukclip, 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, mappable 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.

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

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.

1. INTRODUCTION AND TERMS OF REFERENCE

Metago Environmental Engineers (Pty) Ltd commissioned Earth Science Solutions (ESS (Pty) Ltd.) to undertake a pedological survey for the Langer Heinrich Uranium Expansion Project. The work was undertaken in May of 2009. A total area of approximately 3,800ha (3,578.86ha of Mineral Lease Area, and 245,76ha of Pipeline Route) was investigated in the course of the studies undertaken, with a variation in the intensity of the study depending on the potential for impact to the site. Areas proposed for open cast mining, and construction of structures that will disturb the soils were looked at in more detail, with the Powerline Route and general mining right area that will have limited or no material impact was studied on a much less intensive reconnaissance base.

Using this philosophy, the area of concern was assessed and an understanding of the baseline conditions obtained. The study has been delineated as two distinct regions, with the proposed area for open cast mining being demarcated separately from the area that is proposed to be disturbed by construction activities for the processing plant expansion, the heap leach pad area and associated support infrastructure. The alternatives for the main infrastructure and support facilities are included in Figures 1b and 1c (Tailings Storage Facility, Return Water Dams, and Workshops etc.

For the purposes of the soils study, the two areas were considered as one unit and were mapped on a reconnaissance grid base, while more detailed studies of the infrastructural sites were looked at in more detail.

The proposed mining project and associated development (Langer Hienrich Project) is located in the western central region of Namibia, to the east of Gawibmund, south of Karabib and north off the C28 route to Windhoek in the east (Refer to Figure 1a). The area forms part of the Namib Naukluft National Park.

The specialist studies undertaken for the proposed expansion project have been structured so as to satisfy the requirements of the environmental legislation as tabled in the Environmental Management Act, 7 of 2007. Although the proposed EIA regulations have not yet been promulgated in a final form, the draft regulations and Namibian Environmental Policy for EIA (1995) have been used as a guideline where relevant. In this regard, a project specific environmental impact assessment (EIA) is required as part of the application for the proposed expansion project.

This specialist study has been written as a standalone document, but should be read as part of the larger EIA and forms a part of the baseline study used in the determination of the impacts as well as informing the environmental management plan (EMP).

To this end, a number of soil parameters were mapped and classified using the standard *Taxonomic Soil Classification System for South Africa (Mac Vicar et al, 2nd edition 1991)* and the S.A. Chamber of Mines Land Classification System of rating.

The objectives of the study were to:

- Survey the areas that are required for additional infrastructure and that have not previously been disturbed;
- Classify the different soil types and produce a soils distribution map;
- Confirm the natural land capabilities;
- Provide a profile of the soils, including the effective depth and occurrence of sub soils;
- Analyze properties and define characteristics of the soil such as nutrient content, chemistry, capability to support ecosystem functionality;
- Assess the cumulative impacts on soils and land capability, and
- Have input, together with Metago, other specialists and LHU, into project alternatives and management measures going forward.

Historically, the area proposed for the expansion project was conservation land managed as part of the Namib Naukluft National Park, with the change to mining lease area in the recent past when the Langer Heinrich project was initiated.

With the ever-increasing competition for land, it has become imperative that the full scientific facts for any particular site are known, and the effects on the land to be used by any other proposed enterprise must be evaluated, prior to the new activity being implemented (NEMA).

This document describes the in-field methods used to classify and describe the *in-situ* and *colluvial derived* soils, rates the land capability based on the soils information, climate and topographic variables, and gives details of the pre mining/construction situation as a baseline to the proposed planning. The impact assessment and mitigation scenarios are based on a recognised system with inputs from the results of the site (in-field) survey and an interpretation of the field results.

The findings of this investigation are based on a pedological survey involving a number of specialists in differing fields of expertise (a sedimentologist, geochemist and morphologist) and the interpretation of the resulting data.

Figure 1a Locality Plan



Figure 1b Proposed Mining Plan – Option A

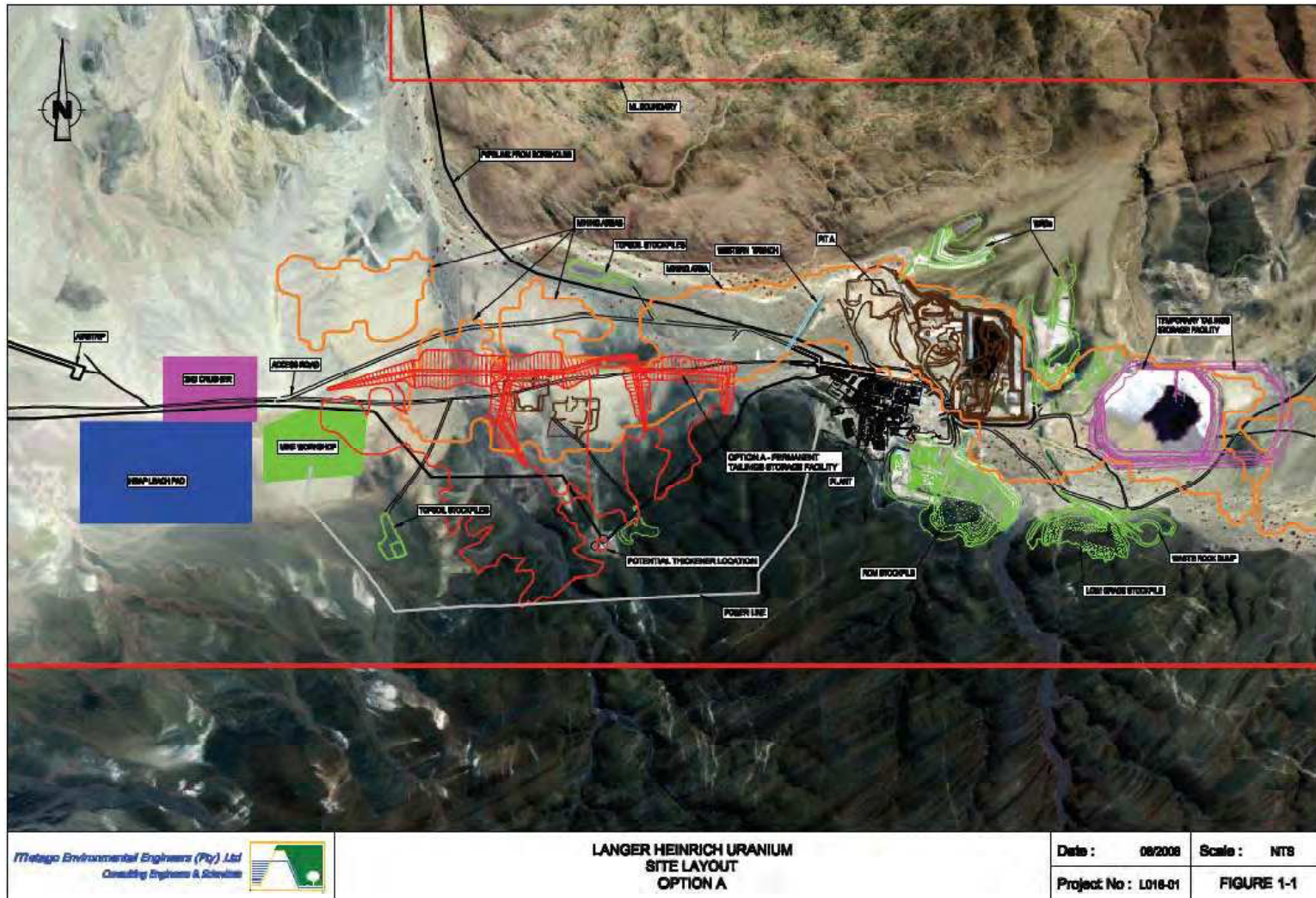
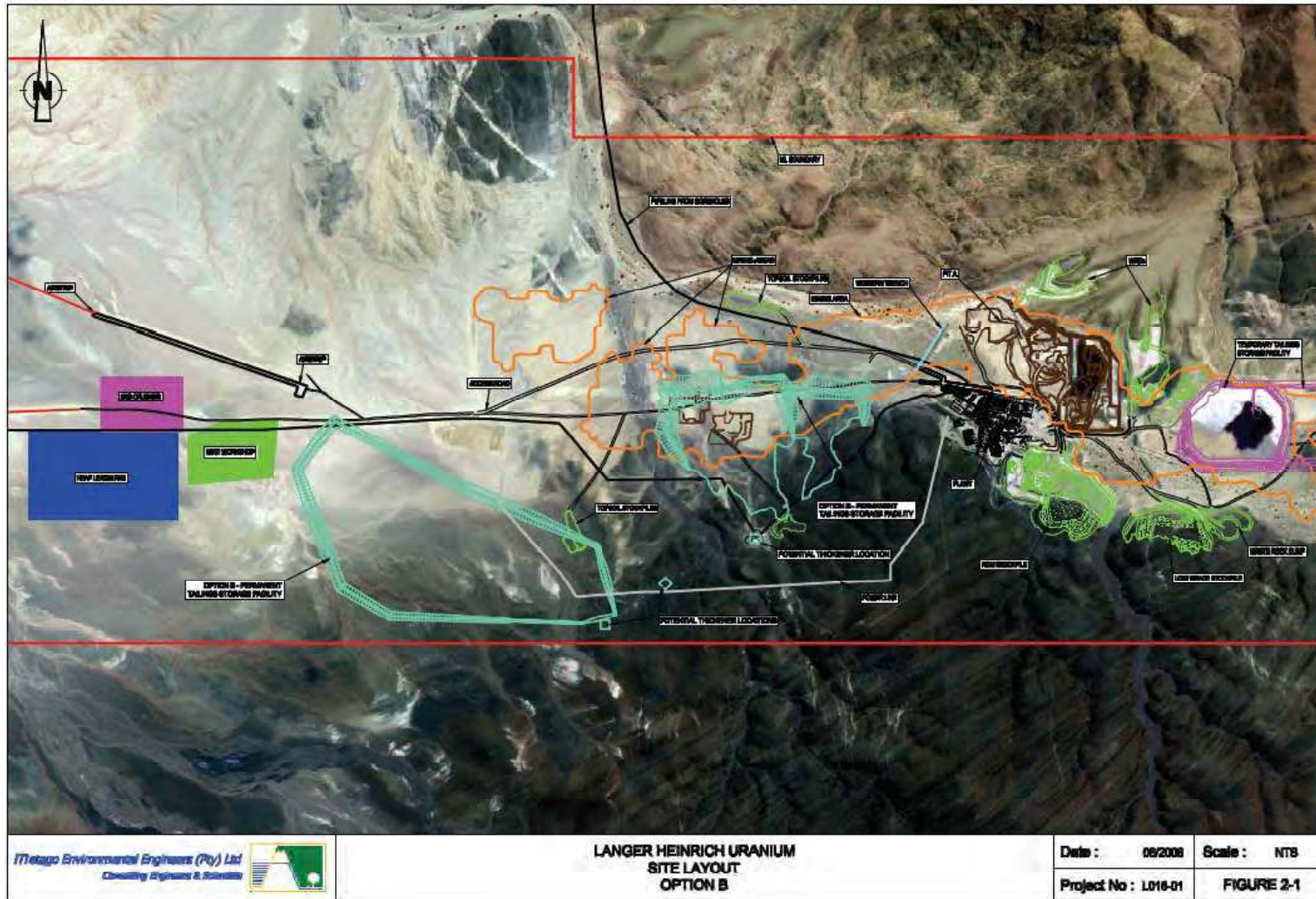


Figure 1c Proposed Mining Plan – Option B



2. DESCRIPTION OF THE PRE-CONSTRUCTION ENVIRONMENT

2.1 Soils

2.1.1 Data Collection

Review of published reports and maps

A significant amount of engineering and geotechnical information was made available by the client, with specific reference being made, and information used from the EIS and Knight Hall Hendry work that was undertaken for the founding conditions of the existing infrastructure (Existing Plant, Plant Access Road and Borrow Pits) and road design. This information was invaluable in understanding the underlying conditions, and reduced the need for digging additional deep excavations to understand the inhibiting layers that could not be hand augered.

No specific reference to this information has been made. However, reference is made to the general trends noted, and extrapolation of detailed sections have been used in obtaining a more in depth understanding of the areas covered by the reconnaissance studies (Road Survey etc.).

The government survey geological maps and descriptions were used in an understanding of the general lithological setting for the area, and discussions with the local site geologist helped in understanding the possible pedogenic processes that are unique to desert environments.

Little information is/was available on the influence and effects of the evaporites on the local ecological balance and sustainability of the systems that naturally occur. These hard carbonate horizons are common to the environment, and, while these are possibly not of consequence to the mining operation or management of the project from an engineering perspective, they are believed to be of great importance to the biodiversity and systems that make these areas habitable.

The aerial imagery supplied by the client is recent and proved to be of great assistance in the mapping of the soil patterns outside of the detailed study.

The area proposed for the expansion of the infrastructural development is generally outside of the alluvial plains in close proximity to the existing infrastructure and to the west, while the additional open cast mining is confined almost exclusively to the Gawib River and its associated flood plain. At least three options (Refer to Figures 1 b and 1c) have been tabled for the placement of the infrastructure and tailings facility. The final positioning of these will be dependent on the findings of the EIA and associated studies.

Significant large areas of presently unaffected land will be impacted by the proposed new development, with associated affects on the areas that lie adjacent to the proposed development. The sub linear nature of the proposed mining by open cast methods of the river gravels and sands, and areas of adjoining colluvial deposits, will by its nature affect not only the actual river (Gawib), but also the banks of the river which include the transitional zone (colluvial deposits and potential wetland soils) and the lower slope in-situ soils that occupy the areas where bench mining will be required outside of the riverine environment into the hard rock geology. Sufficient overburden is stripped to allow for the depth of mining to be achieved.

In addition to the hard copy data and electronically generated files supplied by the client, a meeting with the staff on site and with the local ecologist was extremely beneficial to the understanding of local conditions and proposed expansion methodology. Our thanks is extended to the environmental personnel on the mine, and Ms. Antje Burke – Specialist Ecologist for their input and assistance.

Of significance to the soils study is the underlying geology, with a moderately complex suite of rocks that make up the overall sequence and which have had a profound effect on the weathered materials. In its simplicity, the area can be described as follows:

The mining lease area is situated in the Damara Belt syncline. The oldest beds consist of psammitic rocks of the Nosib Group overlain by several thousand metres of polytuffaceous rocks of the Gawib Group and the Khomas Subgroup all of Proterozoic Age (Refer to Figure 2).

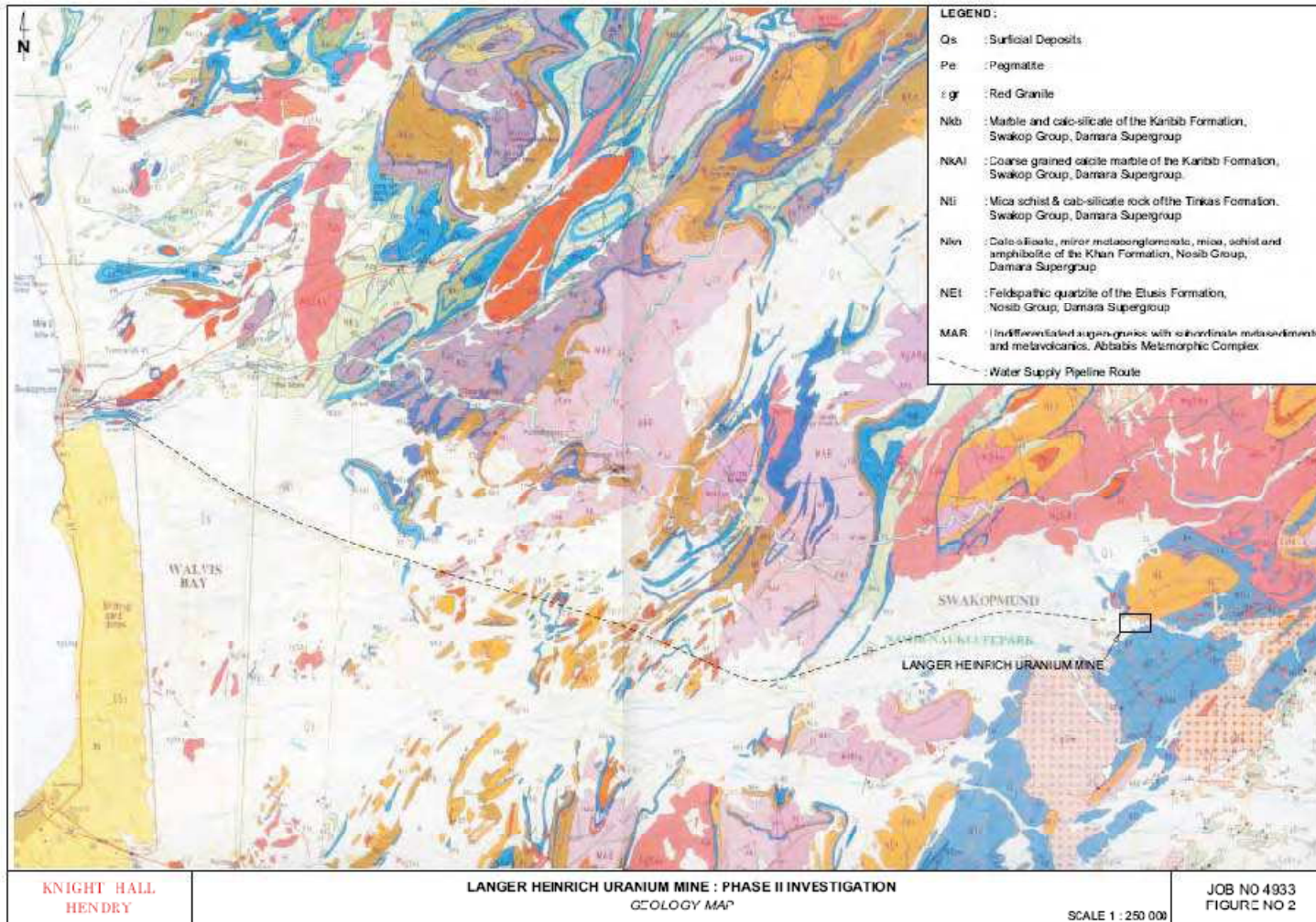
Weathering and erosion of uraniferous granites are thought to be the source of uranium that precipitated to form secondary deposits such as Langer Heinrich. The lowermost rocks of the Damara Sequence form the Langer Heinrich Mountain anticline. Overlying these quartzites are schists comprised of interbedded fine-grained metapelite, metagreywacke and calcisilicate beds. The uraniferous fluvial sediments in the Langer Heinrich Formation were deposited under flash-flood conditions in deep palaeochannels.

The sediments of the Langer Heinrich deposit consist mainly of angular clastic basement debris forming alternating bands of conglomerate, gravel, and clay, the coarser fractions predominating. Carnotite is the main uranium mineral, occurring interstitially and bounded by larger coarser clasts, and has maximum development in zones of high porosity.

Depths to the base of the palaeochannel are variable and sedimentary thicknesses up to 150m have been recorded. Grades tend to be highest in a central core zone with uranium distribution totally irregular and discontinuous forming pods, veins lenses and particularly cavity fillings.

It is these complexes of lithologies combined with the topographic changes that produce the complex of differing soil polygons mapped Refer to Figure 2.1.1a, 2.1.1b and 2.1.1c).

Figure 2 Regional Geological Map



Field Work

The reconnaissance pedological study of the site was performed using various different scales of mapping, with the majority of the area being assessed on a reconnaissance base of between 300m and 500m depending on the complexity of the soil patterns noted and the degree of impact that is likely to occur. The areas of potential impact by construction and open cast mining were assessed in more detail, all be it that the grid base was again varied depending on the degree of complexity and the accessibility to the natural environment.

The surveys were undertaken during May of 2009. In addition to the grid point observations, a representative selection of the soil Forms mapped were sampled and analysed to determine their chemistry and physical attributes. The soil mapping was undertaken on a 1:10,000 scale (Refer to Figure 2.1.1a, 2.1.1b and 2.1.1c) orthophotographic base.

A total area of approximately 3,800ha (3,578.86ha of Mineral Lease Area, and 245.76ha of Pipeline Route) was covered in the course of this study.

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

In all cases, the observation points were excavated to a depth of 1,500mm or until refusal was obtained. Immediately after completing the classification of the profiles, the excavations were backfilled for safety reasons.

Standard mapping procedures and field equipment were used throughout the survey. Initially, geological map of scale 1:250,000 and topocadastral maps at a scale of 1:50,000 were used to provide an overview of the area, while colour imagery at a scale of 1:10,000 was used as the base map for the soil survey.

The fieldwork comprised a site visit during which profiles of the soil were examined 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. Significant background information was obtained from the Scoping Document supplied (Metago 2009)

The pedological study was aimed at investigating/logging and classifying the soil within the area of potential disturbance. 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 System (Mac Vicar et al, 2nd edition 1991)*

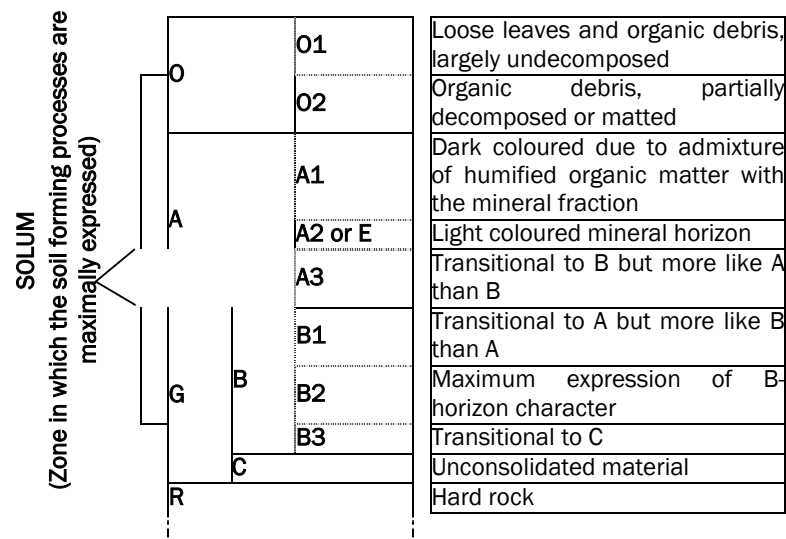
The Taxonomic Soil Classification System is in essence a very simple system that employs two main categories or levels of classes, an upper level or general level containing Soil Forms, and a lower, more specific level containing Soil Families.

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 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 such as:
 - ❖ 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 minerals and/or peds)
 - ❖ Compaction (from surface)
- iii. Determine from i) and ii) the appropriate Soil Form
- iv. Establishing provisionally the most likely Soil Family

Table 2.1.1 Typical Arrangement of Master Horizons in Soil Profile



Arrangement of master horizons

Figure 2.1.1a Soil Polygon Map – Mining Lease Area West

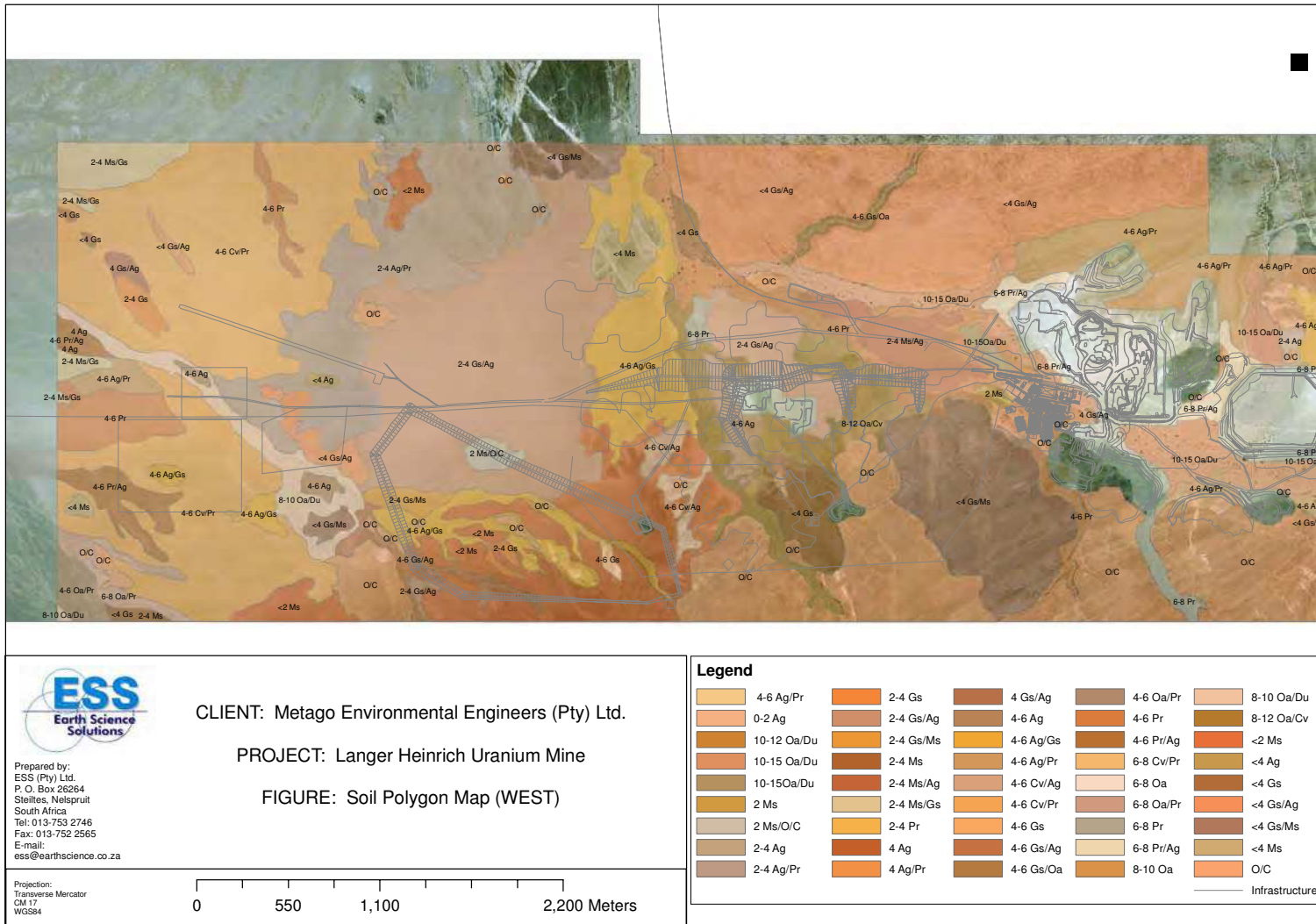


Figure 2.1.1b Soil Polygon Map – Mining Lease Area East

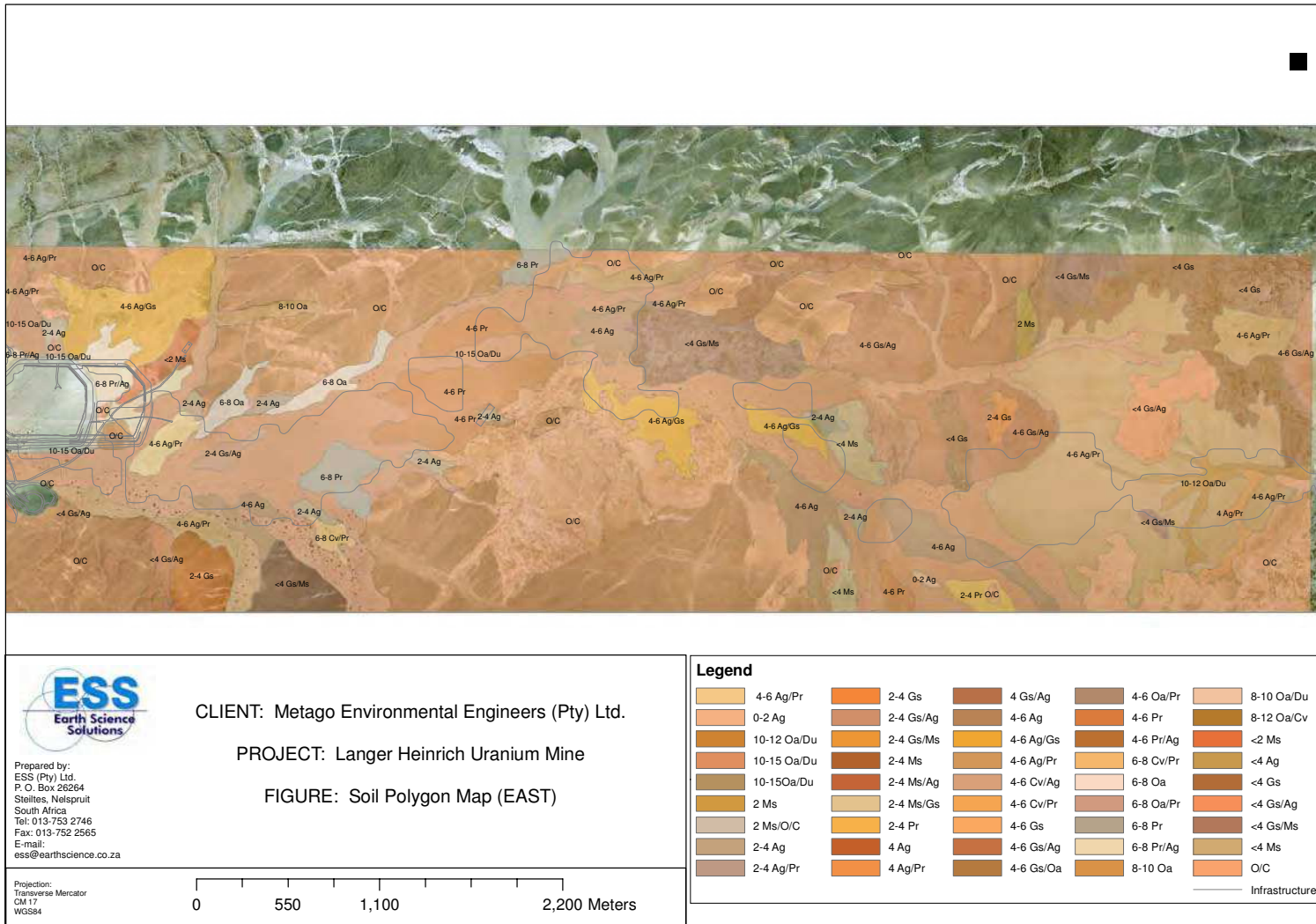
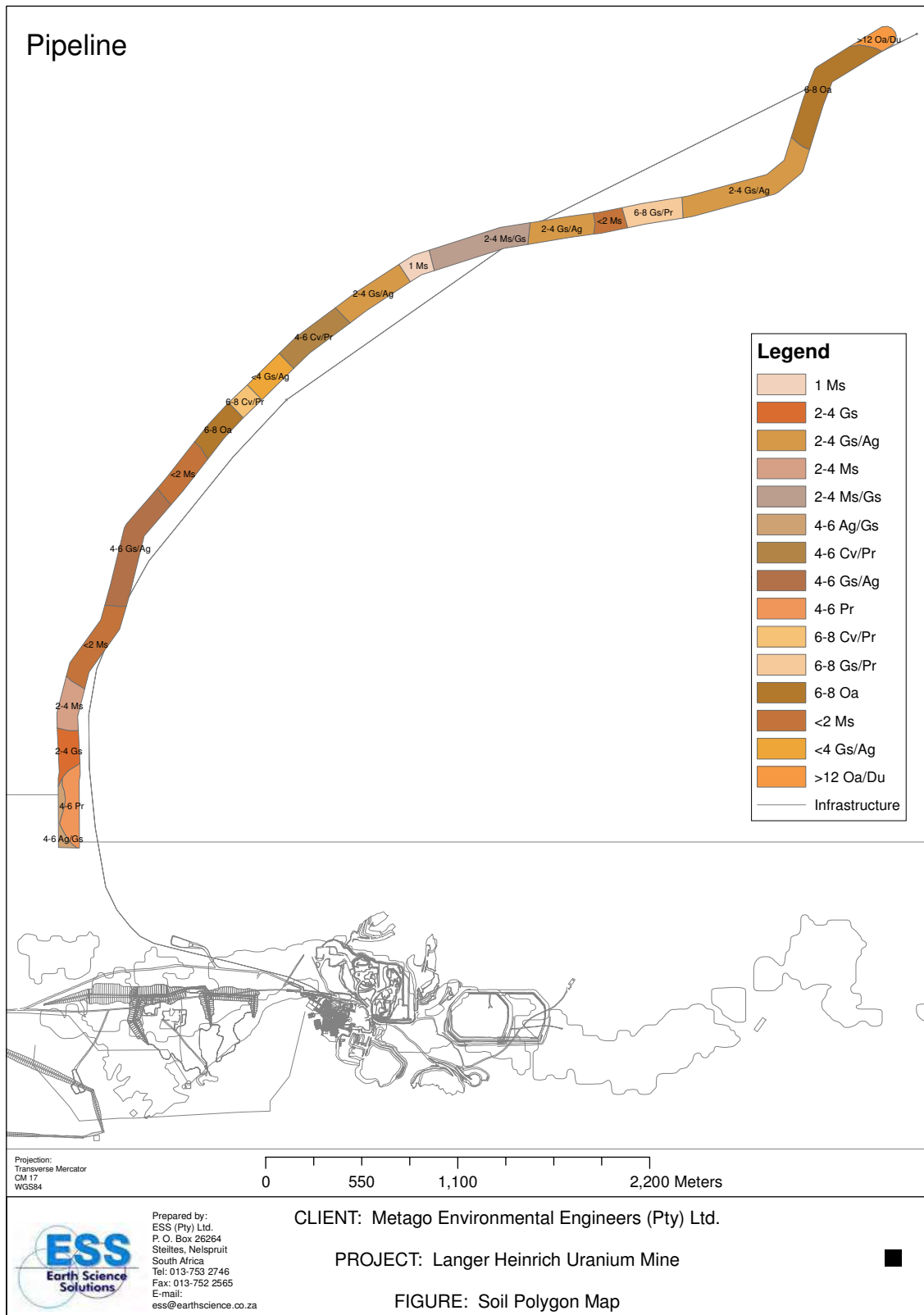


Figure 2.1.1c Soil Polygon Map – Pipeline Route



2.1.2 Description

Soil Forms Identified

The soils encountered can be broadly categorised into three groupings, with those associated with the more mountainous terrain being distinctly different from the alluvial materials found in the river, while a transition zone or suite of soils that form the colluvial derived soils was mapped between the erosive environment and the depositional environment (transition zone).

As with any natural system, the transition from one system to another is often complex with multiple facets and variations. However, in simplifying the trends mapped include the following major soil Forms:

- A group of generally shallow to very shallow poorly structured fine to very fine grained sandy loams and silty loams that are associated with the in-situ materials outside of the river or stream environments. These soils are generally founded on a hard rock base or lithocutanic horizon, and returned poor vegetative cover for the most part. These soils are represented by Mispah and Glenrosa Form soils with pockets of shallow Clovelly and Fernwood Forms within extensive areas of outcrop.
- In contrast, the stratified river alluvial sediments associated with the river channels and flood plain of the Gawib River are generally deep to very deep (800mm to greater than 1,500mm), and vary in texture from fine grained silt and sand to pebble and cobble size materials with occasional boulder inclusions. Radically differing extremes of energy environments are noted throughout the profile, with at least four distinct episodes of extreme flood events (high energy events) noted.

In almost all cases mapped, the stratified alluvials are founded on a hard rock base that comprises a thick sequence of evaporite derived calcrete (Calcium Carbonate). This underlying layer is significant to the overall ecological success of the area in its natural state, and forms an/the impermeable layer that holds water close to the surface, but below the sands where it is available to animals and plants, but does not easily evaporate. Concentration of salts and stores of nutrients within these soils are again a sensitive balance that should be noted. These soils are dominated by the Oakleaf Form, with variations from Fernwood to Augrabies and Prieska Forms across the catena.

- In the transition zone, are a variation of shallow colluvial derived materials that are founded on calcrete and/or hard rock (typically Glenrosa and Glencoe Forms), with areas of moderately deep sandy loams and sandy clay loams that returned moderately high clay contents and a degree of structure (weak crumbly to weak blocky). These characteristics are not generally found in the alluvial materials or the in-situ derived rocky desert areas. These materials are generally moderately well sorted, and do not exhibit the distinctive stratification of the river sediments (typically, Oakleaf, Clovelly, Hutton, Prieska and Augrabies).

In terms of the Taxonomic Classification the major soil types encountered include those of the orthic phase Hutton, Clovelly, Oakleaf, Dundee, Mispah, Glenrosa, Augrabies and Prieska Forms with minor areas of hydromorphic form soils including the Pinedene and Avalon Forms.

All areas (inclusive of waterways) included in the study have been captured in a GIS format and mapped according to their soil classification nomenclature and soil depth (decimetres). The spatial areas of the specific polygons have been tabled below (Tables 2.1.2a and 2.1.2b, and in Figures 2.1.1a, 2.1.1b and 2.1.1c (Soil Polygon Maps of the Mining Lease Area and Pipeline Route respectively) as a function of the total area surveyed.

Table 2.1.2a Soil Coverage – Mining Lease Area

Soil Code	Soil Name	Soil Depth	Area (Ha)	% of Area
<2 Ms	Mispah	0-2	140.18	3.92%
<4 Ag	Augrabies	2-4	1.24	0.03%
<4 Gs	Glenrosa	2-4	111.54	3.12%
<4 Gs/Ag	Glenrosa/Augrabies	2-4	244.74	6.84%
<4 Gs/Ms	Glenrosa/Mispah	2-4	169.08	4.72%
<4 Ms	Mispah	2-4	31.14	0.87%
0-2 Ag	Augrabies	0-2	0.83	0.02%
10-12 Oa/Du	Oakleaf/Dundee	10-12	12.96	0.36%
10-15 Oa/Du	Oakleaf/Dundee	10-15	354.45	9.90%
2 Ms	Mispah	0-2	5.96	0.17%
2 Ms/O/C	Mispah/Outcrop	0-2	4.97	0.14%
2-4 Ag	Augrabies	2-4	14.95	0.42%
2-4 Ag/Pr	Augrabies/Prieska	2-4	120.16	3.36%
2-4 Gs	Glenrosa	2-4	27.13	0.76%
2-4 Gs/Ag	Glenrosa/Augrabies	2-4	227.99	6.37%
2-4 Gs/Ms	Glenrosa/Mispah	2-4	6.13	0.17%
2-4 Ms	Mispah	2-4	1.18	0.03%
2-4 Ms/Ag	Mispah/Augrabies	2-4	26.18	0.73%
2-4 Ms/Gs	Mispah/Glenrosa	2-4	23.59	0.66%
2-4 Pr	Prieska	2-4	5.35	0.15%
4 Ag	Augrabies	2-4	0.81	0.02%
4 Ag/Pr	Augrabies/Prieska	2-4	6.13	0.17%
4 Gs/Ag	Glenrosa/Augrabies	2-4	3.24	0.09%
4-6 Ag	Augrabies	4-6	72.13	2.02%
4-6 Ag/Gs	Augrabies/Glenrosa	4-6	155.61	4.35%
4-6 Ag/Pr	Augrabies/Prieska	4-6	269.37	7.53%
4-6 Cv/Ag	Clovelly/Augrabies	4-6	10.64	0.30%
4-6 Cv/Pr	Clovelly/Prieska	4-6	286.05	7.99%
4-6 Gs	Glenrosa	4-6	1.71	0.05%
4-6 Gs/Ag	Glenrosa/Augrabies	4-6	123.93	3.46%
4-6 Gs/Oa	Glenrosa/Oakleaf	4-6	6.65	0.19%
4-6 Oa/Pr	Oakleaf/Prieska	4-6	8.92	0.25%
4-6 Pr	Prieska	4-6	139.35	3.89%
4-6 Pr/Ag	Prieska/Augrabies	4-6	19.14	0.53%
6-8 Cv/Pr	Clovelly/Prieska	6-8	3.59	0.10%
6-8 Oa	Oakleaf	6-8	13.53	0.38%
6-8 Oa/Pr	Oakleaf/Prieska	6-8	11.17	0.31%
6-8 Pr	Prieska	6-8	27.13	0.76%
6-8 Pr/Ag	Prieska/Augrabies	6-8	33.11	0.93%
8-10 Oa	Oakleaf	8-10	9.32	0.26%
8-10 Oa/Du	Oakleaf/Dundee	8-10	29.63	0.83%
8-12 Oa/Cv	Oakleaf/Clovelly	8-12	58.21	1.63%
O/C	Outcrop		759.74	21.23%
Total Area (Ha)			3578.86	100.00%

Table 2.1.2b Soil Coverage – Pipeline Route

Soil Code	Soil Name	Soil Depth	Area (Ha)	% of Area
<2 Ms	Mispah	0-2	34.06	13.86%
<4 Gs/Ag	Glenrosa/Augrabies	2-4	8.54	3.47%
>12 Oa/Du	Oakleaf/Dundee	>12	5.35	2.18%
1 Ms	Mispah	0-1	5.74	2.34%
2-4 Gs	Glenrosa	2-4	7.96	3.24%
2-4 Gs/Ag	Glenrosa/Augrabies	2-4	54.07	22.00%
2-4 Ms	Mispah	2-4	9.12	3.71%
2-4 Ms/Gs	Mispah/Glenrosa	2-4	19.23	7.82%
4-6 Ag/Gs	Augrabies/Glenrosa	4-6	3.63	1.48%
4-6 Cv/Pr	Clovelly/Prieska	4-6	13.80	5.62%
4-6 Gs/Ag	Glenrosa/Augrabies	4-6	23.33	9.49%
4-6 Pr	Prieska	4-6	10.86	4.42%
6-8 Cv/Pr	Clovelly/Prieska	6-8	4.92	2.00%
6-8 Gs/Pr	Glenrosa/Prieska	6-8	11.17	4.55%
6-8 Oa	Oakleaf	6-8	33.98	13.83%
Total Area (Ha)			245.76	100.00%

2.1.3 Soil Chemical and Physical Characteristics

A suite of representative samples from the differing soil forms/types were taken and sent for analyses for both chemical as well as physical parameters. A select number of samples were submitted, each sample containing a number of sub samples from a particular soil Form or Type, which is representative of the area in question, thus forming a composite sample, which in turn is representative of the soil Form rather than a specific point sampled.

2.1.3.1: Soil Chemical Characteristics

Sampling of the soils for nutrient status was confined where possible to areas of undisturbed land. However, some of the better soil and rock exposure, and areas where sampling could be undertaken are associated with the trench structures that had been dug across the proposed open cast mining areas in the east just behind the temporary tailings facility, and in the west, close to the existing open cast structures being mined. These sites not only exposed the profile from surface to the hard rock or evaporite contact, but also exposed the section/catena across the complete range of soil forms from the rocky outcrops through the colluvial derived materials that form the river banks to the centre of the river channel. Samples were taken at intervals down the profile within the disturbed trench environment, and where present, samples of the stockpiled topsoil's were also taken for analysis.

These results are intended as representative indications of the pre-mining conditions, and are at best a reconnaissance representation of the baseline conditions. These results will need to be augmented with on-going sampling prior to and during the mining operation, and will give a baseline from which to compare the soil chemical and physical conditions during the rehabilitation process and at closure

Table 2.1.3.1 Analytical Soils Results

Results for: Langer Heinrich

LAB. No.		9-05909	9-05910	9-05911	9-05912	9-05913	9-05914	9-05915	9-05916
YOUR REF.		Uranium Mine TS/A	TS/B	LH 117	LH 94a	LH 94b	LH 94c	LH 89	LH 68
pH (KCl)	pHunit	8.25	8.15	8.10	8.35	8.45	8.50	8.60	8.65
Calcium as Ca	mg/kg	2996	2890	3969	3174	1787	2567	1463	1880
Magnesium as Mg	mg/kg	76	74	110	94	109	119	66	81
Potassium as K	mg/kg	116	124	272	144	156	187	77	102
Sodium as Na	mg/kg	163	198	467	125	167	198	19	14
"S" Value	me%	16.6	16.2	23.5	17.6	11.0	15.2	8.1	10.4
Ca Ratio	me%	90	89	85	90	81	85	90	90
Mg Ratio	me%	4	4	4	4	8	7	7	6
K Ratio	me%	2	2	3	2	4	3	2	3
Na Ratio	me%	4.2	5.2	8.6	3.1	6.5	5.6	1.0	0.6
Phosphorus as P*	mg/kg	27	20	25	26	30	27	39	69
Zinc as Zn	mg/kg	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.3
Copper as Cu	mg/kg	0.6	0.6	0.6	0.6	0.4	0.7	0.5	0.7
Aluminium as Al	mg/kg	1.3	1.1	1.2	0.8	0.5	0.8	0.6	0.7
Org.Mat. As C	%	0.12	0.11	0.17	0.07	0.08	0.32	0.10	0.11
Clay	%	2	4	7	4	2	2	2	2

* P = Ambic 1 Extraction method.

Results for: Langer Heinrich

LAB. No.		9-05917	9-05918	9-05919	9-05920	9-05921	9-05922	9-05923
YOUR REF.		LH 85	LH 44	LH 29	LH 39	LH 101	LH 48	LH 42
pH (KCl)	pHunit	8.70	8.75	8.65	8.50	8.65	8.45	8.55
Calcium as Ca	mg/kg	1567	1872	4000	2253	1240	1304	1699
Magnesium as Mg	mg/kg	70	75	89	81	51	77	70
Potassium as K	mg/kg	103	102	214	86	50	92	57
Sodium as Na	mg/kg	15	14	428	102	23	11	50
"S" Value	me%	8.7	10.3	23.1	12.6	6.9	7.4	9.4
Ca Ratio	me%	90	91	86	89	90	88	90
Mg Ratio	me%	7	6	3	5	6	9	6
K Ratio	me%	3	3	2	2	2	3	2
Na Ratio	me%	0.7	0.6	8.0	3.5	1.4	0.6	2.3
Phosphorus as P*	mg/kg	63	68	13	46	48	59	45
Zinc as Zn	mg/kg	0.2	0.3	0.1	0.2	0.1	0.1	0.2
Copper as Cu	mg/kg	0.6	0.5	0.9	0.5	0.4	0.5	0.6
Aluminium as Al	mg/kg	0.5	0.3	0.4	0.5	0.4	1.0	1.0
Org.Mat. As C	%	0.17	0.14	0.14	0.11	0.01	0.15	0.10
Clay	%	2	2	11	2	2	2	2

* P = Ambic 1 Extraction method.

High Values
Low Values

The results of the laboratory analysis returned light textured soils with a pH (KCl) of between 8.1 and 8.7, a base status ranging from 6.9me% to 17.6me% (mesotrophic to dystrophic leaching status), and nutrient levels reflecting generally high levels of calcium and sodium, but deficiencies in the levels of magnesium, potassium, phosphorous, copper, aluminium and zinc, with exceptionally low levels of organic carbon matter and low clay content (as low as 2%).

The slightly more structured (weak crumby) 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.

Growth of vegetation in these mediums will require the addition of nutrients at start up. It should be noted that the addition of nutrients in the form of commercial fertilisers are potential pollutants to the riverine and groundwater environment if added in excess.

2.1.3.1.1 Soil acidity/alkalinity

In general, it is accepted that the pH of a soil has a direct influence on plant growth. This may occur in a number of different ways including:

- ❖ The direct effect of the hydrogen ion concentration on nutrient uptake;
- ❖ Indirectly through the effect on major trace nutrient availability; and by
- ❖ Mobilising toxic ions such as aluminium and manganese, which restrict plant growth.

A pH range of between 6 and 7 most readily promotes the availability of plant nutrients to the plant. However, pH values below 3 or above 9, will seriously affect, and reduce the nutrient uptake by a plant.

The dominant soils mapped in this area are slightly alkaline (pH = 8.1 to 8.7), but still generally within the accepted range for good nutrient mobility.

2.1.3.1.2 Soil salinity/sodicity

In addition, to the acidity/alkalinity of a soil, the salinity and/or sodicity are of importance in a soils potential to sustain growth.

Highly saline soils will result in the reduction of plant growth caused by the diversion of plant energy from normal physiological processes, to those involved in the acquisition of water under highly stressed conditions. Salinity levels of <60 mS/m will have no effect on plant growth. From 60 – 120 mS/m salt sensitive plants are affected, and above 120 mS/m growth of all plants is severely affected.

In addition soil salinity may directly influence the effects of particular ions on soil properties. The sodium adsorption ratio (SAR) is an indication of the effect of sodium on the soils. At high levels of exchangeable sodium, certain clay minerals, when saturated with sodium, swell markedly. With the swelling and dispersion of a sodic soil, pore spaces become blocked and infiltration rates and permeability are greatly reduced. The critical SAR for poorly drained (grey coloured) soils is 6, for slowly draining (black swelling as found in this site) clays it is 10 and for well drained, (red and yellow) soils and recent sands, 15.

Generally, the soils mapped in this area are non saline in character, but could be prone to sodic development if good water management is not practiced.

2.1.3.1.3 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 sodium. However, levels of Zn, P, Mg, Al, Cu and K are generally lower than the optimum required.

Significantly large areas of soil with a lower than acceptable level of plant nutrition were mapped across the mineral lease area. These poor conditions for growth were further compounded by the high permeability and low clay and carbon contents of the majority of the soils.

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

2.1.3.1.4 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) of the soils.

The low organic carbon content and very low clays are detrimental to the exchange mechanisms, as it is these elements which naturally provide exchange sites that serve as nutrient stores. These conditions will result in a 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 1-5 me/100g (<5 me/%).

Generally, the CEC values for the soils mapped in the area are moderate to low, due to the low clay contents.

2.1.3.1.5 Soil organic matter

The soils mapped are all extremely low in organic carbon as would be expected for a desert environment. This factor coupled with the moderately low to low clay contents for the majority of the soils mapped will adversely affect the erosion indices for the soils, with a very high index prevailing for the majority of the materials classified.

2.1.3.2 Soil Physical Characteristics

The majority of the soils mapped exhibit apedel to single grained structure, low to very low clay content and a eutrophic leaching character. These conditions are conducive to the formation of evaporites, with extremely low rainfall (<100mm/yr) and high evaporation (1450mm/yr), hard pan calcification at or close to surface is common due to precipitation of calcium and magnesium as the water evaporates. This layer is an extremely important feature of the biosphere and is expected to contribute to the sustainability of the ecological systems in these desert environments.

In addition to the unique characteristics of the area, the normal soil forming processes are at work, with in-situ soils with shallow depth and sandy loam textures characterising the rocky hill slopes and mountainous rocky desert, while the colluvial derived soils are characterised by deeper, sandy loams and sandy clay loams that bound on a hard rock or calcrete "C" horizon.

These soils are prone to erosion if the vegetative cover is removed and the topsoils are disturbed.

In contrast to the colluvial derived materials, the alluvial soils or stratified alluvium is characterised by variable texture and grain size distribution through the profile, with a mixture of fine and coarse materials in layers, a result of flood events and changes in the depositional energy of the events with time.

The ability for water to easily move through this environment (high permeability), and the high evaporation common to this climate, results in the characteristic evaporite or "calcrete" layer at surface or just below the sandy alluvials.

A large proportion of the overall area to be affected by the mining operations and its associated infrastructure is underlain by soils with a more sensitive nature to heavy traffic. This will affect both compaction and erosion of the materials if not well managed

2.1.3.3 Characteristics of different Soil Groups

2.1.3.3.1 The Heavy Clay Rich Soils

The presence of clay rich soils is almost nonexistent in the areas that are to be disturbed with some kaolinite associated with weathering of the calcite/calcium carbonates in the base of the soil profiles. The presence of these weathered clays will need to be identified during the mining process, and where possible, these materials must be stored for future use at rehabilitation.

Soils derived from the more calcium rich parent materials (calc silicates and hardpan calcrete) that form the hard base to the soil profile exhibit some degree of structure, with weak crumbly and weak blocky structure occurring where weathering of these materials occurs. This saprolitic layer is generally quite thin (<500mm) and underlain by the schists and calc silicates.

Intake rates and drainage through these calcrete layers is slow, forming the underlying inhibiting layers to the soil profile.

2.1.3.3.2 Light Textured -Yellow-brown and Red Apedal soils

The majority of the soils to be disturbed classify as light textured soils that returned high inflow rates, good to very good drainage characteristics and low to very low water holding characteristics. These are of the more sensitive soils in the area, and will erode if not protected from wind and water erosion.

The working of these soils as well as the storage (stockpiling) will need to be well managed.

2.1.3.3.3 Shallow soils

The generally shallow rooting depths of the soils that dominate the area (<400mm) are associated with the resistant lithologies that form the host rock geology, while the deeper soils are associated with the alluvial flood plains of the Gawib River and the transitional zone in between. Shallow soil depths within the river environment is generally associated with the calcrete layer.

2.1.3.4 Soil distribution

The distribution of the soils (Figure 2.1.1 Soil Polygon Map) is closely linked to the depositional mechanisms and environment, along with the topography and parent materials from which the soils are derived.

2.1.4 Soil Erosion and Compaction

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

An index of erosion (I.O.E.) for soils is then determined by multiplying the “K” value by the slope percentage. Erosion problems may be experienced when the Index of Erosion is greater than 2.

The “K” value is used to express the “erodibility” of a particular soil form. Erodibility is defined as the vulnerability or susceptibility of a soil to erosion. It is a function of both the physical characteristics of that soil as well as the treatment of the soil. Erodibility ratings are expressed as:

Resistant	“K” factor = <0.15
Moderate	“K” factor = 0.15-0.35
Erodible	“K” factor = 0.35-0.45
Highly erodible	“K” factor = >0.45

The average “Erosion Indices” for the dominant soil forms on the study site are shown in Table 2.1.4. The majority of the soils mapped can be classified as having a high erodibility index. This is largely ascribed to the very low clay content of the soils and a generally low to very low organic carbon content.

These factors are enhanced on the more mountainous terrain by the low level of vegetative cover and steepness of the slopes, while the valley environments and desert plains are characterised by very low erosion indices due to the flatness of the terrain, and the generally better vegetative cover associated with a better soil cover.

The vulnerability of the “B” horizon to erosion once/if the topsoil is removed must not be underestimated.

The concerns around erosion and inter alia compaction, are directly related to the disturbance of the protective vegetation (all be it spars) cover and topsoil that will be disturbed during any mining or construction operation. Once disturbed, the 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. The effects in this desert environment will be even greater and of greater consequence to the success of any rehabilitation process.

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.

Table 2.1.4 Erodibility of Differing Soil Forms

Soil Form	Erodibility Index	Index of Erosion (I.O.E.)
Augrabies	Moderate to High	1.40 - 1.65
Prieska	Moderate	1.35 - 1.45
Mispah	Moderate to High	0.95 - 1.15
Glenrosa	Moderate to High	1.35
Hutton	Moderate	0.85 - 0.95

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 Mines (1991) has been used. The land capability of the study area was classified into four classes (wetland, arable land, grazing land and wilderness) according to the *Guidelines*, 1991. 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 Mines 1991)

<p><u>Criteria for Wetland</u></p> <ul style="list-style-type: none">• Land with organic soils or supporting hygrophilous vegetation where soil and vegetation processes are water determined. <p><u>Criteria for Arable land</u></p> <ul style="list-style-type: none">• Land, which does not qualify as a wetland.• 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. <p><u>Criteria for Grazing land</u></p> <ul style="list-style-type: none">• Land, which does not qualify as wetland or arable land.• Has soil, or soil-like material, permeable to roots of native plants, that is more than 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. <p><u>Criteria for Wilderness land</u></p> <ul style="list-style-type: none">• Land, which does not qualify as wetland, arable land or grazing land.

2.2.2 Description

The "land capability classification" as described above was used to classify the land units identified during the pedological survey. In summary, of the total area investigated 3,578ha, approximately 1646ha is considered to be of a low intensity grazing land potential and 1932ha is of a highly sensitive wilderness or conservation land potential. Figures 2.2a, 2.2b and 2.2c and Tables 2.2.1.1a and 2.2.1.1b illustrates the distribution of land capability classes.

Table 2.2.2.1a Land Capability – Mining and Infrastructure

Land Capability	Area (Ha)	% of Area
Grazing	1646.61	46.01%
Wilderness	1932.25	53.99%
Total Area (Ha)	3578.86	100.00%

Table 2.2.2.1b Land Capability – Pipeline Route

Land Capability	Area (Ha)	% of Area
Grazing	107.04	43.56%
Wilderness	138.71	56.44%
Total Area (Ha)	245.76	100.00%

Arable

The very low rainfall of this area (<100mm/a) limits the utilization potential of the study area to very low intensity grazing and wildlife conservation. The land utilization ability to obtain a return on any cropping system will fall short of the national average (a measure used in the Land Capability Rating System – Refer Table 2.2.1 above), and thus negates the idea of even the deep soils being a potential for arable cultivation.

Grazing

The areas that classify as grazing land are generally confined to the shallower and transitional zones that are moderately 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, especially since only the subsoils (at a depth of 500mm) are periodically saturated. 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.

Wilderness / Conservation

The majority of the area in question classifies as either conservation or wilderness land based on the shallow rocky nature of the materials and the inability of the materials to sustain a crop yield that is at least equal to the current national average.

Wetland

The wetland areas are defined in terms of the wetland delineation guidelines, which use both soil characteristics, the topography as well as vegetation criteria to define the domain limits.

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.

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 subsoils. Wetland soils occur within the zone of groundwater influence.

There are no areas of true wetland (wetness too deep below surface - must be within 500mm of surface) soils present within the study area, with zones of wetness at depths of 700mm and greater having been noted within the riverine (alluvial) zone, thus relegating these zones to "Transitional" wetland or moist grassland status.

Figure 2.2a Land Capability Plan – Mining Lease Area - West

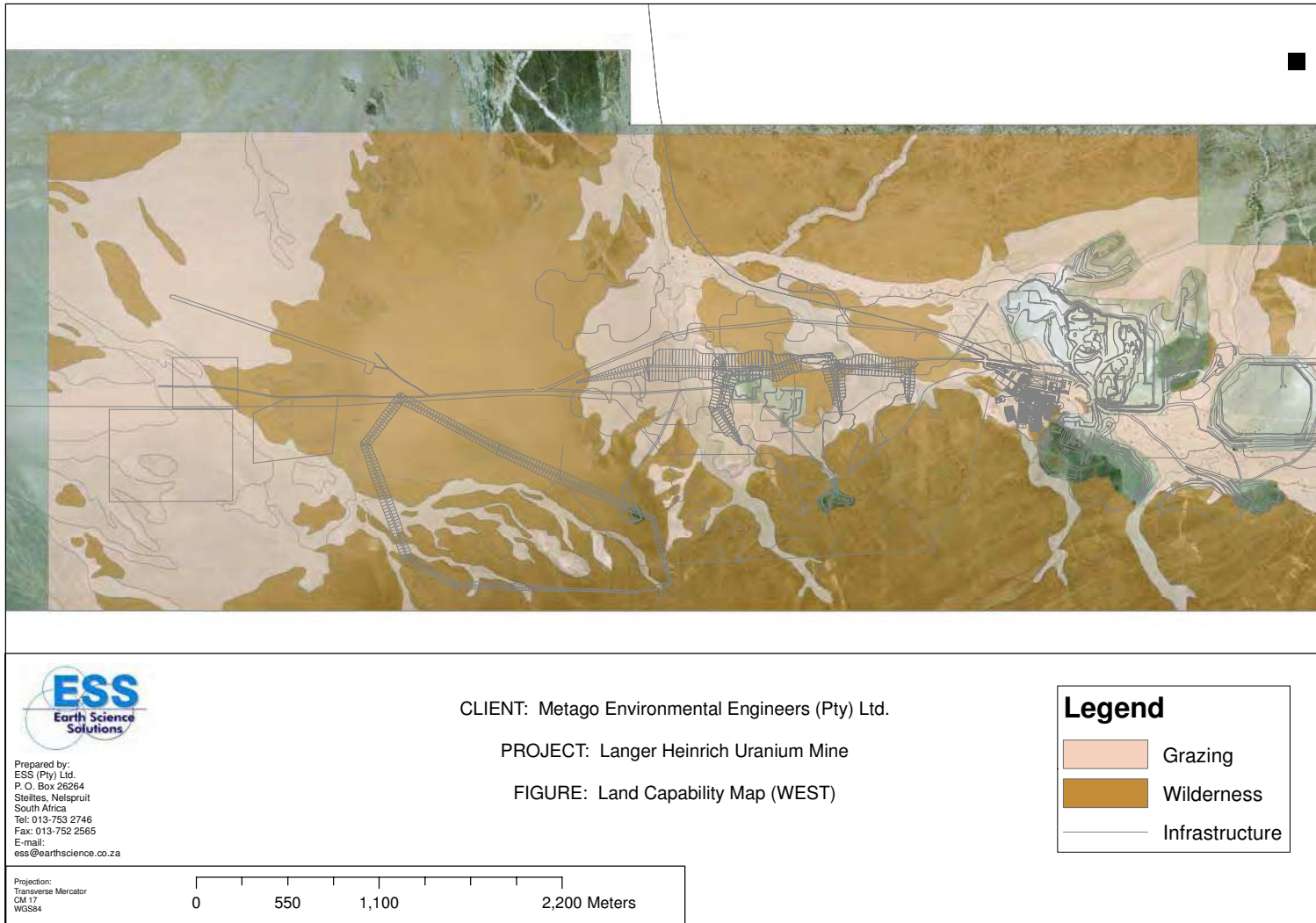


Figure 2.2b Land Capability Plan – Mining Lease Area – East

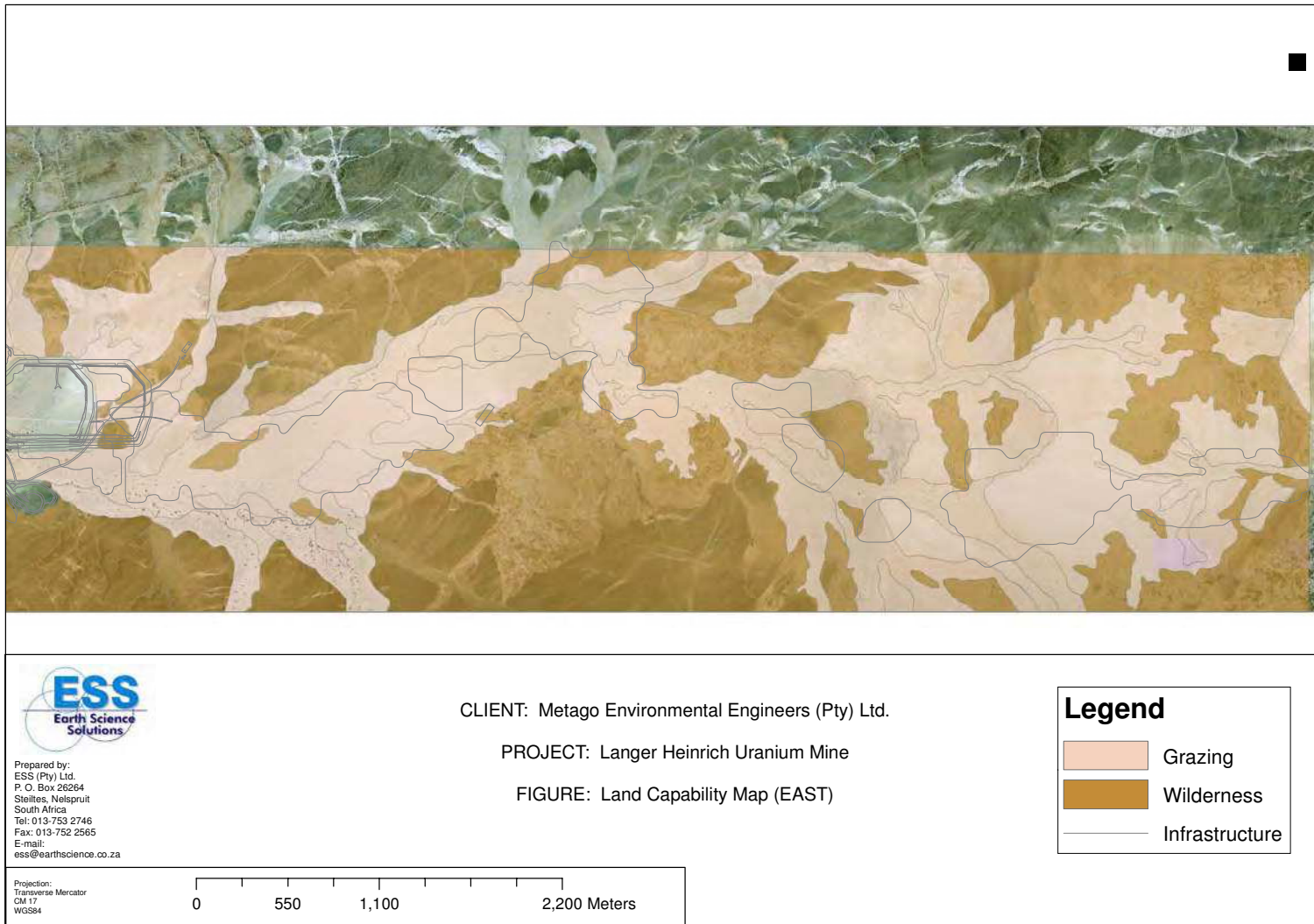
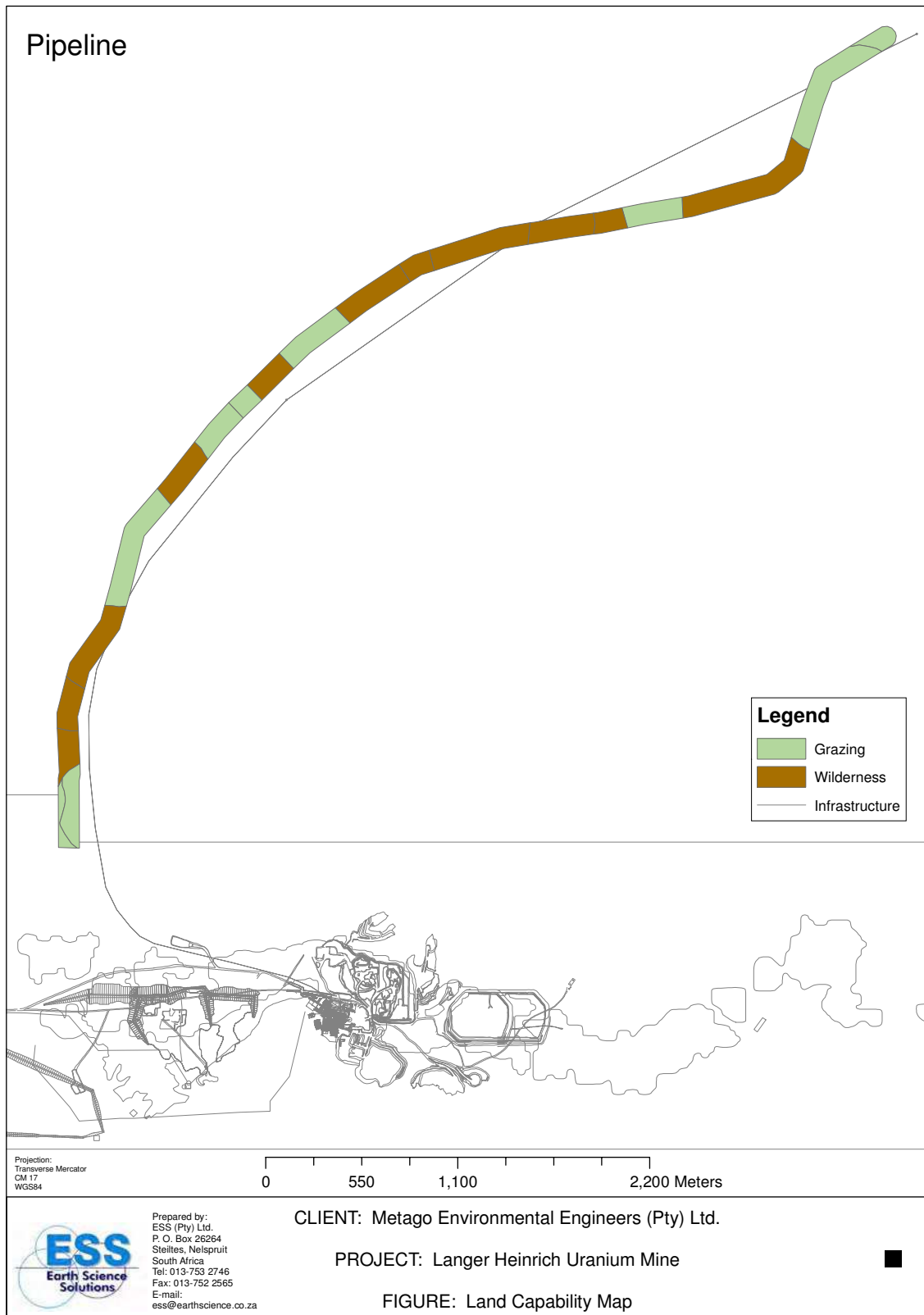


Figure 2.2c Land Capability Plan – Pipeline Route



3 ALTERNATIVES ASSESSMENT

The alternatives assessment has been based on the three scenarios tabled by the client and lead consultants. All three of the scenarios support the same positioning and area of open cast mining, with the positioning of the Tailings Storage Facility and the Mining Infrastructure along with the Beneficiation Plant being the main concerns considered as part of the environmental impact assessment criteria.

The attached Figures 1b and 1c show the two extremes (Option A and Option B respectively), with alternative C being a hybrid of Options A and B. Option C disturbs less surface area than both A or B, while the above ground part of the tailings dam is confined to the area between the plant and the major drainage/Reid Wash (ie. to the west of the plant but to the east of the drainage line), and forms the eastern part of the option B dam, with the additional new infrastructure (heap leach pad, satellite crusher, satellite mine workshop) located on the western side of the drainage line in the flat areas as per option A.

In the cause of assessing Options A and B a person is by default covering any hybrid which covers Option C.

As part of the overall assessment to the area of concern, it was important to give the project leaders a recommendation as to the best alternative/s for the proposed project. The concerns to the soil and land capability are many and varied, but for the most part these are best mitigated by reducing the total area that is going to be disturbed.

In line with this philosophy, and with the study having covered the areas of concern for both options A and B and by default option C, it was the conclusion of this study, that Option C is the most environmentally desirable option.

The major difference between the two diverse options shown pictorially are the backfilling of the open cast mining areas with tailings in the central portion and a significant amount of above surface tailings being deposited across the prominent valley, and the infrastructure being kept as close to the existing area of concern – Option A (Figure 1b), while Option B (Figure 1c) moves all of the new infrastructure to the west, and assumes a large above ground TSF to the west of the major drainage line. The third/hybrid option (Option C) is regarded as the most desirable option as the prominent drainage line is left open, the open cast pits are backfilled to surface with tailings thus reducing the significantly large Tailings Storage Facility to the west of the drainage line, and reducing the area of coverage by the processing and related facilities to the west. In brief, the area to be impacted is reduced to a minimum.

In assessing the impacts of the facilities and infrastructure (existing and proposed) on the soils of the area, the alternatives have been considered, and the most appropriate alternative based on the impact to the soils has been recommended.

4. IMPACT ASSESSMENT

The impact assessment has been undertaken for both the existing operation (Mining and Infrastructure) as well as the proposed expansion. The impacts of the construction phase for the existing open cast mining and its related infrastructure is not relevant as it has already been completed and is presently operational (Refer to Table 4a – Existing Operational Infrastructure). However, the potential impacts of the open cast mining and the expansion to the facilities (Satellite Mine Workshop, Additional Crushing and Scrubbing Capacity, a Heap Leach Pad, Processing Plant, Tailings and Thickener Plant, Water Supply and Management and Waste Management) have been assessed and rated according to the South African Integrated Environmental Management Information Series (DEAT 2002) and the criteria and methodology developed by Theo Hacking (Hacking 1998).

Table 4a Existing Mining and Related Activities at Langer Heinrich

Infrastructure	Description
Access Road	<ul style="list-style-type: none"> The access road to the mine joins the regional C28 road. All employees, contractors, input materials, waste materials and product that are transported to or from site, are transported on the access road and C28. From the C28 the traffic flows are split between the roads to Walvisbay, Swakopmund and Windhoek.
Airstrip	<ul style="list-style-type: none"> A 1.3km gravel runway (for emergency landings) is located on the gravel plains on the western side of the ML, about 300m north of the access road.
Barren stockpiles	<ul style="list-style-type: none"> Two barren stockpiles (rejected from the processing plant). One east of the process plant and the other south of the one waste rock dump (WRD A).
Exploration Camp Site	<ul style="list-style-type: none"> An exploration drilling contractor camp is located in the south east of the ML approximately 5km from the processing plant. Approximately 30 people are staying there.
Contractor lay-down area	<ul style="list-style-type: none"> This is a site that is used to accommodate any short term contractors. It consists of a yard with storage and ablution facilities. These ablution facilities discharge into a French drain system. It is located within the ML to the west of the process plant and was the original construction camp
Conveyors	<ul style="list-style-type: none"> Conveyors are used to transport material in the front end of the process plant between the crushers, scrubbers and some of the stockpiles.
Exploration drill rigs and network of holes	<ul style="list-style-type: none"> Exploration drilling is continuous. It is used to upgrade the mineral resource on a yearly basis as well as to assist with detailed mine planning.
Explosives	<ul style="list-style-type: none"> The explosives compound is located on the eastern side of the current temporary tailings storage facility (TSF) and is accessed by a single controlled-access road. It houses heavy energy fuel (HEF) storage tanks and an unloading bay. There are two fenced in explosives magazines. Management of the explosives compound and of all blasting activities is currently subcontracted to Bulk Mining Explosives (BME).
Fuel storage facilities	<ul style="list-style-type: none"> There are a number of above ground diesel and petrol fuel tanks located in covered and/or bunded areas.
Internal haul roads	<ul style="list-style-type: none"> There are a number of internal dirt haul roads within the ML. Trucks are used to haul run of mine (ROM), mine residue waste and other equipment and material.
Laboratory	<ul style="list-style-type: none"> Samples of solids, liquids, pulp and resin from the processing plant are analyzed at the assay laboratory. Analyses includes: <ul style="list-style-type: none"> XRF (Uranium & Vanadium mainly) Ore Moisture Titrations Total suspended solids The laboratory is also equipped for analysis of environmental (dust and water) samples. The results from the analyses are used for process control, metal accounting purposes and water quality monitoring. Any excess sample volumes are returned to the process before the sample containers are cleaned out for re-use.
Low grade	<ul style="list-style-type: none"> Currently low grade ore material (discard from the open pits) is stockpiled to the

stockpiles	east of the processing plant. Provision has been made for additional stockpiles in the ML, as required.
Offices, stores and Workshop	<ul style="list-style-type: none"> The main office complex (offices and ablution facilities) is located within the security fence directly north of the processing plant. An engineering office block is located between the process dam and the Engineering workshops. Activities associated with the workshops include painting, grinding, welding, repairs and general maintenance. The front end process control room is located inside the laboratory building, which is situated near the counter current decantation (CCD) tanks in the plant area. The back end central process control room is located in the recovery building. Karibib mining contractors has its own office and workshop, with a fuel storage facility and tyre workshop, directly east of the main office complex. In relatively close proximity to the engineering workshop, there is an engineering storage yard for new large equipment and salvageable equipment. The following items are kept at the store: reagents - Sodium Carbonate; Sodium bicarbonate; Sodium chloride; Flocculant; Hydrogen peroxide; Sodium hydroxide; Sulphuric Acid; and Ferrous sulphate, personal protective equipment, paint, and general maintenance equipment.
Open pit mine	<ul style="list-style-type: none"> Mining is performed using conventional open pit mining methods. In accordance with current approvals, the dimensions of the total mined area will be in the order of an 11.5km (east-west) long pit, plus a number of smaller pits over an additional 4.0km. The average width (north-south) will be 400m, and the average depth will be 30m, although the deepest point will be 80m below the ground surface. Current mining areas include Pit A, Pit B and Pit D. These are situated north-east and west of the processing plant.
Open pit dewatering facilities	<ul style="list-style-type: none"> Water seeping into the pits is pumped via pipelines to dedicated water storage areas to be used for dust suppression or for use as process water in the plant.
Ore stockpiles (RoM)	<ul style="list-style-type: none"> The mined out ore grade material is stockpiled directly east of processing plant on the ROM pad and south of Pit A.
Pipelines	<ul style="list-style-type: none"> A number of internal pipelines are used for the transportation of water, gas, diesel, air, reagents, process plant solution and tailings. The main external pipeline is for water supply from NamWater. This pipeline is from the Omdel aquifer. It has a number of pump stations along route. LHU has authorisation to purchase 1.5 million m³ per year from this source but currently only uses 1 million m³ per year. A shorter pipeline supplies water from the boreholes in the Swakop River. LHU has authorisation to receive 0.5 million m³ per year from this source but currently only uses 50 to 70 000m³ per year.
Powerlines, substation and diesel generator	<ul style="list-style-type: none"> Electricity is supplied from the NamPower Kuiseb substation close to Walvisbay. This powerline is approximately 50 km in length and supplies approximately 16.6 MVA. A diesel generator facility, with an approved capacity of 30 MVA, is used to augment NamPower. There is an on-site substation and internal powerlines.
Processing Plant	<ul style="list-style-type: none"> The processing plant is located towards the middle of the ML. Key process components are described in Table 4-2.
Sewage Plant	<ul style="list-style-type: none"> Two bio-treatment sewerage plants (trickling filter plant) are located directly west of the main office buildings. This combined facility has a capacity of 50m³/day.
Tailings Storage Facility (TSF)	<ul style="list-style-type: none"> The current temporary TGF is strategically located above part of the ore body to the east of the office buildings and processing plant. Once this facility is replaced with the approved permanent facility to the west of the processing plant it will be re-mined and processed. The permanent TSF will primarily be placed in mined out pits as backfill material, but a portion of the tailings will remain above ground.

	<ul style="list-style-type: none"> Supernatant water is pumped back to the processing pond via a pipeline, to be recycled back into the process plant.
Topsoil stockpiles	<ul style="list-style-type: none"> There are four topsoil stockpiles. These are located on the western and eastern sides of the processing plant.
Waste rock dumps (WRDs)	<ul style="list-style-type: none"> There are two WRDs located to the north and east of mining Pit A and additional provision has been made adjacent to the permanent TSF. Over the mine life the number of WRDs within the ML will increase as required.
Waste - Radioactive waste disposal facility	<ul style="list-style-type: none"> A temporary disposal site for radioactive contaminated material/waste has been established within one of the waste rock dumps. . This radioactive contaminated waste includes inter alia: old personal protective equipment, drums, pipes, etc.
Waste - General and non-radioactive hazardous waste handling facilities	<ul style="list-style-type: none"> Hazardous waste (non radioactive) includes inter alia: fuels, chemicals, lubricating oils, hydraulic and brake fluid, paints, solvents, acids, detergents, resins, brine, solids from sewerage and sludge. General waste includes industrial and domestic non-hazardous waste. Facilities are provided for sorting and temporary storage prior to removal and disposal Final disposal of these waste types is by contractors at licensed facilities in Walvisbay and Swakopmund
Water storage facilities	<ul style="list-style-type: none"> The lined raw water "turkey" dam stores water that is pumped from the Swakop River. NamWater is stored in three reservoirs to feed the process, in an emergency tank and in a number of potable water tanks The process dam is a lined dam and receives water from the TSF return circuit, the open pits, the treated sewage water circuit, laboratory, wash bays, plant run-off and the process plant circuit. As mining advances, the mined out Pit A and B will be used to contain storm water.
Water treatment	<ul style="list-style-type: none"> A reverse osmosis plant is used to treat water as required.

In essence, the Impact Assessment (Hacking) Methodology is as follows:

The "Significance Rating" of an impact is the product of the consequence and the probability, while the consequence is a function of the severity of the impact, its extent and the expected duration (Refer to Table 4b for Criteria for Assessing Impacts).

i.e. Significance = consequence x probability,

Where: Consequence = severity + spatial extent + duration,

The following sections summarise the potential impacts associated with the proposed construction, operation and closure of the mining and its related infrastructure for both the existing operation and the expansion phase.

Table 4b Criteria for Assessing Impacts

Table 3.1: Criteria for Assessing Impacts

PART A: DEFINITION AND CRITERIA*					
Definition of SIGNIFICANCE		Significance = consequence x probability			
Definition of CONSEQUENCE		Consequence is a function of severity, spatial extent and duration			
Criteria for ranking of the SEVERITY of environmental impacts	H	Substantial deterioration (death, illness or injury). Recommended level will often be violated. Vigorous community action. Irreplaceable loss of resources.			
	M	Moderate/ measurable deterioration (discomfort). Recommended level will occasionally be violated. Widespread complaints. Noticeable loss of resources.			
	L	Minor deterioration (nuisance or minor deterioration). Change not measurable/ will remain in the current range. Recommended level will never be violated. Sporadic complaints. Limited loss of resources.			
	L+	Minor improvement. Change not measurable/ will remain in the current range. Recommended level will never be violated. Sporadic complaints.			
	M+	Moderate improvement. Will be within or better than the recommended level. No observed reaction.			
	H+	Substantial improvement. Will be within or better than the recommended level. Favourable publicity.			
Criteria for ranking the DURATI ON of impacts	L	Quickly reversible. Less than the project life. Short term			
	M	Reversible over time. Life of the project. Medium term			
	H	Permanent. Beyond closure. Long term.			
Criteria for ranking the SPATI AL SCALE of impacts	L	Localised - Within the site boundary.			
	M	Fairly widespread – Beyond the site boundary. Local			
	H	Widespread – Far beyond site boundary. Regional/ national			
PART B: DETERMINING CONSEQUENCE					
SEVERITY = L					
DURATI ON	Long term	H	Medium	Medium	Medium
	Medium term	M	Low	Low	Medium
	Short term	L	Low	Low	Medium
SEVERITY = M					
DURATI ON	Long term	H	Medium	High	High
	Medium term	M	Medium	Medium	High
	Short term	L	Low	Medium	Medium
SEVERITY = H					
DURATI ON	Long term	H	High	High	High
	Medium term	M	Medium	Medium	High
	Short term	L	Medium	Medium	High
			L	M	H
			Localised Within site boundary Site	Fairly widespread Beyond site boundary Local	Widespread Far beyond site boundary Regional/ national
SPATI AL SCALE					
PART C: DETERMINING SIGNIFICANCE					
PROBABILITY (of exposure to impacts)	Definite/ Continuous	H	Medium	Medium	High
	Possible/ frequent	M	Medium	Medium	High
	Unlikely/ seldom	L	Low	Low	Medium
			L	M	H
CONSEQUENCE					
PART D: INTERPRETATION OF SIGNIFICANCE					
Significance		Decision guideline			
High		It would influence the decision regardless of any possible mitigation.			
Medium		It should have an influence on the decision unless it is mitigated.			
Low		It will not have an influence on the decision.			

4.1 Soils

4.1.1 Construction Phase

Issue: **Loss of Utilizable Soil Resource due to – Erosion, Contamination and/or Compaction during construction**

Due to the relative differences between the alluvial gravels with their extremes of materials size (confined to open pit mining mainly), and the colluvial and in-situ desert plains materials that are much better sorted and compacted, the impacts will be different and mitigation measures varied.

Construction for Project

Stripping of utilizable soil, preparation (levelling and compaction) of lay-down areas and pad footprint for stockpiling and berms, opening up of foundations and stockpiling of subsoil and soft overburden, and slope stability where required. Haulage and access road construction and storage of utilizable soils.

Control of dust and loss of materials to wind and water erosion, and protection of materials from contamination (chemical, hydrocarbons and sewage)

The construction phase will impact on all of the proposed mining and developmental activities, but will not apply to the existing infrastructure.

Open cast mining will continue throughout the operational phase, with new areas being opened well after the completion of the beneficiation construction and by-product dumps and stockpiles having been started.

In addition, the soils will need to be stockpiled in different locations throughout the construction and operational phases, with the materials stripped from the areas of infrastructure, roads and pad footprint construction being best stockpiled as close as possible to these features in the form of berms upslope of the facilities, and the open cast soils being stored as low level dumps and/or berms close to the voids to which they are planned to be used.

The gravels and sandy/silty loams of the alluvial deposits being mined for their resource will need to go back into the river (alluvial) channels as close as possible to their original position in the profile once the voids have been backfilled.

Description of Impacts

The loss of the soil resource to the overall environment due to the impact on the soils stripped during the open cast mining activities and the construction of the Waste Rock Dump, Tailings Storage Facility, Water & Waste Management Facilities, Processing Plant, Crushing and Scrubbing Plant, Heap Leach Pad and support infrastructure (Workshops and Offices) will definitely be High (H) in the medium term (life of mine) (M) and restricted to the immediate mining area (L). The overall loss of the soil resource to the environment if un-mitigated will result in a High (H) Significant Rating.

Disturbance of the surface restrictive layers associated with the relatively more sensitive soils will occur for all founding areas, and particularly those associated with the desert plains that will be impacted to some extent in the west, with only the deeper foundations required for the heavier structures (Processing Plant, Crushers and Screening Facilities and dams) and open pit mining areas requiring that the underlying calcrete layer (inhibiting layer) is broken through.

The majority of the existing structures, and all of the proposed structures associated with the expansion phase are outside of the alluvial/riverine environment and are for the most part associated with the moderately shallow to shallow soils of the phyllite outcrop and small areas of the desert plains in the west. The variation in soil sensitivity alters only slightly from the shallow colluvial derived materials adjacent to the phyllite outcrop, while the desert plains and deeper alluvial materials are more extreme.

The impact of removing the topsoils (Utilizable soil – 500mm) will, destroy any surface capping that might be in place, will remove all vegetative cover, and will expose the subsoils to erosion and compaction unless managed and protected.

The moderate to highly sensitive soils (friable soils of the desert plains and colluvial) will be susceptible to erosion and compaction once disturbed, and will be difficult to manage if left unprotected.

It must be emphasised, that the failure to manage the soils will result in the total loss of this resource, with a resultant high significance.

Mitigation/Management Actions

With management, the loss of this primary resource can be reduced and mitigated to a level that is more acceptable.

The impacts on the soils may be mitigated with a number of management procedures, including:

- ❖ Effective soil stripping during the dryer and less windy months when the soils are less susceptible to erosion and compaction. This will assist the stockpiling and vegetative cover to propagate before the following wet season;
- ❖ Effective cladding of the TSF and the minimising of the height of all stockpiles wherever possible will help to reduce wind erosion and the loss of materials;
- ❖ Soil replacement to all areas (temporary) that are not required for the operational phase, and the preparation of a seed bed to facilitate the re-vegetation program for these areas will limit potential erodibility during the operational phase and into the rehabilitation and closure phases.
- ❖ Soil amelioration (cultivation) to enhance the growing capability of the stockpiled soils so that they can be used for rehabilitation at closure and to maintain the soils viability during storage.
- ❖ Backfilling of the open cast voids with soft overburden, discards and/or tailings, and the creation of a **barrier layer** at the soil backfill interface using the relatively more impermeable tailings (<10⁻⁶ cm/day) is recommended as the calcrete layer will have been destroyed and cannot be used to re-create this barrier;
- ❖ Soil replacement and the preparation of a seed bed to facilitate the re-vegetation program and to limit potential erodibility during the rehabilitation process.

Care will need to be taken to keep any wet based soils separated from the dry soils, and to keep all stockpiled soils that are in storage, vegetated and protected from contamination and erosion. These soils will be stripped as “Utilizable Soil” the topsoil and upper portion of the subsoils (B2/1 Horizon) and stored in a position that will be convenient for the final rehabilitation of the facilities during the operational and closure phases.

Only if these materials are available can rehabilitation possibly be executed successfully and cost effectively. It is suggested that an average “Utilizable Soil Depth” (USD) of 500mm be stockpiled where present/available.

Residual Impact

The above management procedures will probably reduce the significance of the impacts to Medium in the long term.

Management	Severity	Duration	Spatial Scale	Consequence	Probability of Occurrence	Significance
Unmanaged	H	M	L	M	H	H
Managed	M/H	M	L	M	M	M

4.1.2 Operational Phase

Issue: **Loss of Soil Usability**

Operation of Project – Cumulative

Loss of soil utilization - Open Cast Mining – on-going soil stripping, Ore processing and the possible contamination by dirty water interaction, dust and/or hydrocarbon spillage and sewage spills, covering of the soils by infrastructure, by-product stockpiles, storage facilities and dumps, compaction by vehicle movement, and erosion and loss of materials due to wind and water interaction with unprotected soils.

Description of Impacts

During the operational phase, all of the construction activities for the infrastructure and major by-product storage structures will have been completed and the crushing and sizing of materials, processing and beneficiation of product started and the deposition of tailings and Heap Leaching will have begun along with the continuous opening up of additional mining areas (Open Pits).

The loss of the soil utilization and the covering of materials for extended periods of time will lead to the compaction and sterilization of the materials for future use. This will definitely result in a High (H) negative impact that will last for the duration of the mining venture within the mining area. The consequence is moderate (M) with an overall significance of High.

The movement of haulage vehicles, the use of access roads and the on-going additions of tailings and by-products to the stockpiles and storage facilities will all impact on the size of area to be impacted, and ultimately on the area of soil affected.

Spillage from moving vehicles of product and possibly hydrocarbons will negatively impact the in-situ materials, while unmanaged dirty water will erode and contaminate the soils that it comes into contact with.

Un-managed soil stockpiles and soil that is left uncovered will be lost to water and wind erosion, and will be prone to compaction if left unprotected.

The preservation of the thin evaporite capping will be impossible to retain or protect over areas where the soils have been stripped, and it will be difficult to re-produce during the storage stage.

In contrast, but of similar concern, is the presence of the semi impermeable barrier layer that forms below many of the alluvial gravels mapped.

This material is believed to be the cause of a perched water table within the alluvial gravels that is of great importance to the ecological sustainability and supports the sensitive bio-diversity of the area

Both of these soils will be impacted upon to differing degrees, and will have been stockpiled for future use during the rehabilitation phase and at closure.

The significance of the impact on these soils during the operational phase will differ both in intensity and duration, with the soils associated with the infrastructure remaining in a stockpile for the full life of the beneficiation process, while the open cast areas are planned to be backfilled as soon as materials become available, and there is the potential for these soils to be replaced at a much earlier stage of the mining process.

It is inevitable however, that the soils will be lost during the operational phase, and possibly for ever if they are not well managed and a mitigation plan is not tabled.

Mitigation/Management Action

The impacts on the stockpiled and stored soils may be mitigated with management procedures including:

- ❖ Minimisation of area impacted;
- ❖ Timeous replacement of the soils so as to minimise the area of disturbance;
- ❖ Effective soil cover and protection from wind (dust) and dirty water contamination;
- ❖ Adequate protection from erosion (wind and water);
- ❖ Servicing of all vehicles on a regular basis and in well constructed and bunded areas, well constructed and maintained oil traps and dirty water collection systems;
- ❖ Cleaning of all roadways and haulage 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, and
- ❖ Soil amelioration 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;

Of consequence during the operational phase will be the minimising of the area that is being impacted by the mining operation and its related support structures and operations, and maintenance of the integrity of the soils. This will require that the soils are kept free of contamination (dust and dirty water), and stabilized and protected from erosion and compaction. The action of wind on dust generated and the loss of materials downwind will need to be considered, while contamination of the soils used on the roads and workshop areas will need to be managed.

The impacts on the differing materials is In line with the proposed management plan to handle the two areas of impact separately (Open Cast areas and areas of Infrastructural development), it will be necessary early in the development of the mining plan to develop dedicated stockpiles for the various materials, as close to the areas of need at rehabilitation.

However, if the soils are stripped to a utilizable depth, and replaced as close as possible to their original position in the topography, the chances of nature being able to restore the systems present prior to disturbance will be better and higher.

More research into the mechanisms that cause the capping phenomena will be needed, and the exact functioning of the evaporite capping in the ecological balance will need to be better understood.

Specialist studies and long term trials to mimic the conditions under which these phenomena occur will be needed, and should be planned for early in the mining plan.

Residual Impact

In the long term, the above mitigation measures will probably reduce the impact on the utilizable soil reserves to a **Medium** impact.

Management	Severity	Duration	Spatial Scale	Consequence	Probability	Significance
Unmanaged	H	M	L	M	H	H
Managed	M	M	L	M	M	M

4.1.3 Decommissioning & Closure Phase

Issue: Net loss of soil potential due to change in materials (Physical and Chemical) and loss of nutrient base.

Decommissioning and Closure – Cumulative
Loss of the soils original nutrient store by leaching, erosion and de-oxygenation while stockpiled. Impact of vehicle movement, dust contamination and erosion during soil replacement and demolishing of infrastructure, slope stabilization and re-vegetation of disturbed areas. Possible contamination by dirty water interaction (use of mine water for irrigation of re-vegetation), dust and/or hydrocarbon spillage from construction vehicles. Positive impacts of reduction in areas of disturbance and return of soil utilization potential, uncovering of areas of storage and rehabilitation of compacted materials.

Description of Impact

The impact will remain the net loss of the soil resource if no intervention or mitigating strategy is implemented. The impact will be high, negative and permanent over the area of disturbance, with a relatively high consequence and resultant high significance. Un-managed closure will result in a long term depletion of soil utilization potential.

Management/Mitigation Actions

Ongoing rehabilitation during the decommissioning phase of the project will probably bring about a net long-term positive impact on the soils.

The initial impact will be high and negative due to the necessity for vehicle movement while rehabilitating the open voids, moving of softs and soils, the demolishing of storm water controls, dams etc and the demolishing of buildings and infrastructure. Dust will be generated and soil will be contaminated and eroded.

The positive impacts of rehabilitating an area are the reduction in the area previously disturbed, the amelioration of the affected soils and oxygenation of the growing medium, the stabilizing of slopes and revegetation of areas decommissioned with a reduction in areas previously subjected to wind or water erosion.

Residual Impacts

On mine closure the long-term negative impact on the soils will probably be of medium to low significance if the management plan set out in Environmental Plan is effectively implemented to reinstate current soil conditions. The success of re-creating a **barrier layer** to the alluvial environment will require further inputs from environmental and rehabilitation engineers with the use of the tailings stream being tabled as a possible mechanism.

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

Management	Severity	Duration	Spatial Scale	Consequence	Probability	Significance
Unmanaged	H	H	L	H	H	H
Managed	M+	M	L	M	H	M/L+

5. ENVIRONMENTAL MANAGEMENT PLAN

Based on the studies undertaken, it has been possible to assess the impacts that mining and beneficiation could potentially have on the soils and their resultant utilization potential, and has aided in a better understanding of the possible management and mitigation measures that could aid in minimising the impacts during the rehabilitation process and at closure.

The management and mitigation measures proposed have been tabled for the different stages of the project, and based on the soil forms that will be impacted or affected and the resultant utilization change an environmental management plan (EMP) has been suggested. The plan caters for the construction, operation and decommissioning stages of the project, and gives recommendations on the stripping and handling of the soils during the construction and operation of the project, with recommendations given for the rehabilitation and ultimate closure of the facility. It is imperative that a full and detailed EMP is implemented if the economics of mine closure are to be understood, and the relative positioning and timings of materials handling are to be aligned with the mining plan.

All alluvial gravels and associated materials that are not going to be mined, but which might be impacted by the proposed TSF, will be impacted permanently, and will require that the topsoils (Utilizable soil – 500mm) are stripped and stored for possible utilization as capping to the TSF and Heap Leach Pads at closure.

Figure 5a Proposed Stripping Plan (WEST)

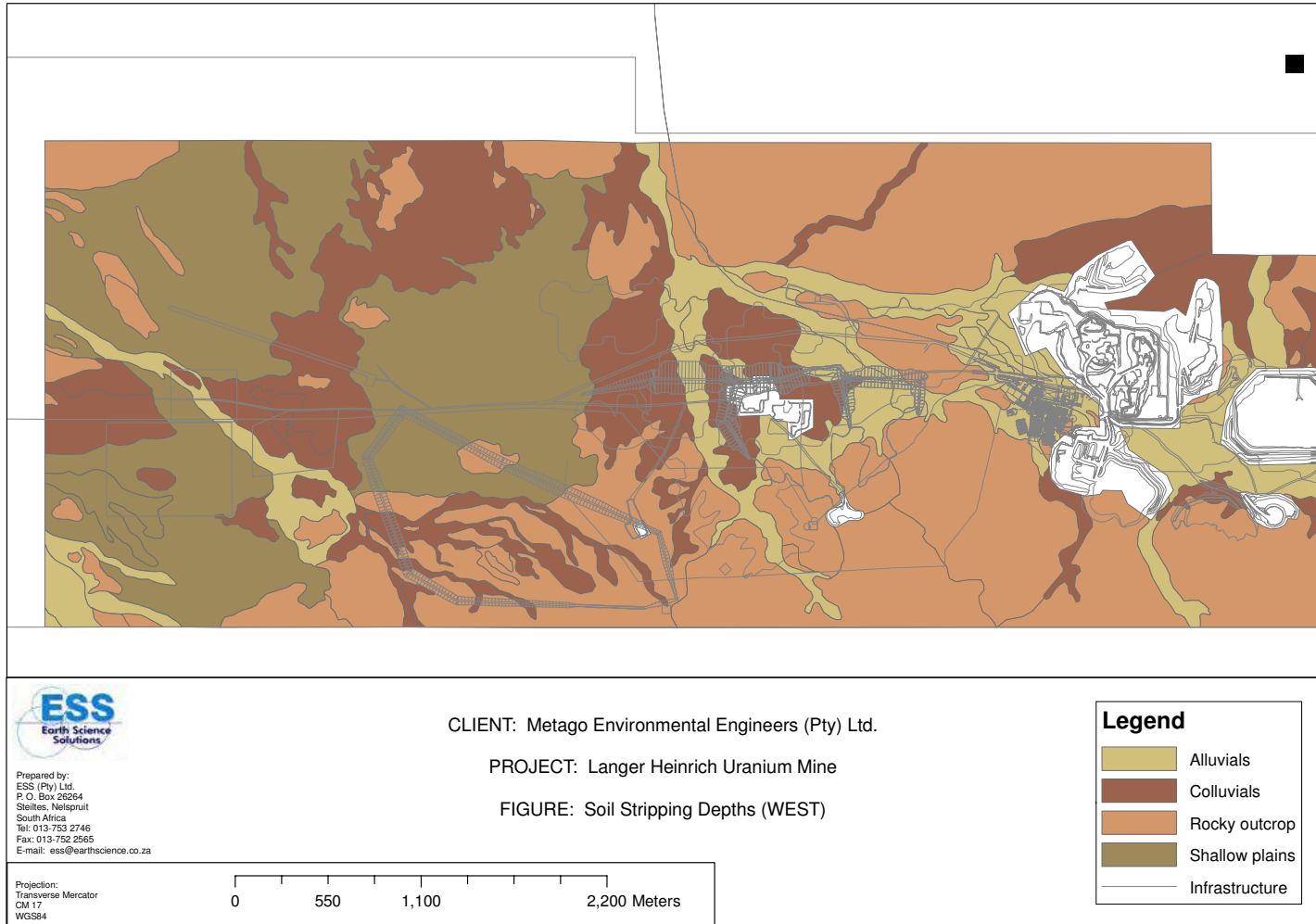
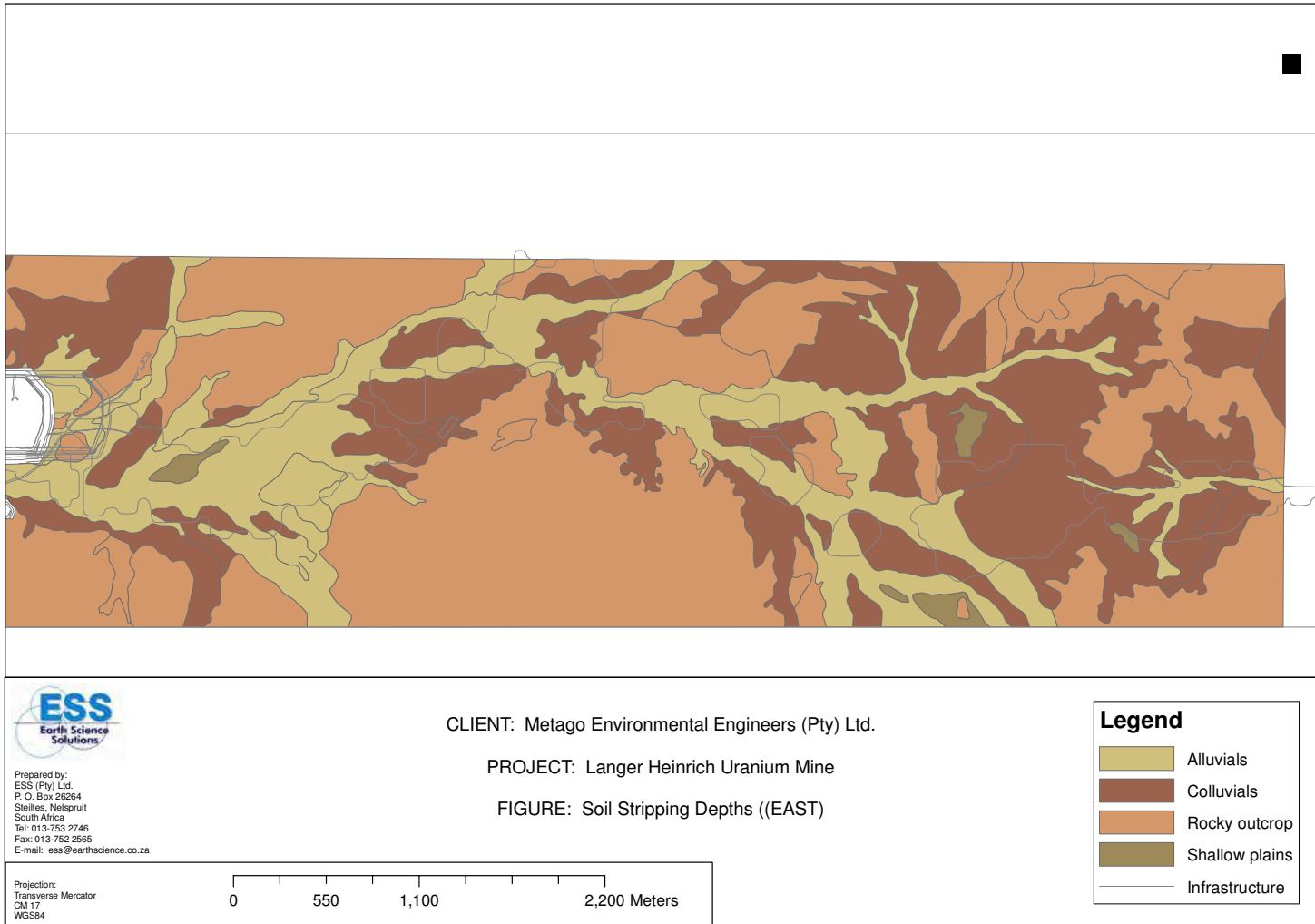


Figure 5b Proposed Stripping Plan (EAST)



5.1 Construction Phase

Soil Stripping and Handling

In considering any management plan for soils it is imperative that the soil physical and chemical composition are known as these will be exceptionally important in obtaining a utilizable material at decommissioning and/or during rehabilitation. The method of stockpiling and general handling of the soil will vary depending on its composition.

Table 5.1 – Construction Phase – Soil Conservation 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 recommended 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. Utilizable soil (Topsoil and upper portion of subsoil B2/1) must be handled and stockpiled separately from the lower "B" horizon and all softs (decomposed rock).
		Stripping	The "Utilizable" soil will be stripped to a depth of 500cm or until hard rock is encountered. These soils will be stockpiled together with any vegetation cover present (only large bushes to be removed prior to stripping). The total stripped depth should be 500mm, where 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.
		Designation of Areas	Soils stockpiles will be demarcated, and clearly marked to identify both the soil type and the intended area of rehabilitation.

The sandy and silty loams (low to very low clay contents) that form the topsoils, along with the upper portion of the subsoils (B2/1 Horizon) within which the majority of the nutrient store occurs (**Utilizable Soil**) will need be stripped and stockpiled for use at closure.

The concept of stripping and storage of all UTILIZABLE soil is tabled as a minimum requirement and as part of the overall Soil Utilization Guidelines.

In terms of the "Minimum Requirements", usable 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 types of soil encountered in a project area. It does not differentiate between topsoil (orthic horizon) and other subsoil horizons.

Soil stripping requirements are set to enable the mining company to achieve post mining land capabilities stipulated by the management plan and are based on pre-mining land capability assessment for the area in question. Pre-mining grazing land capability is the norm that is aimed for in most situations post mining. However, in this unique, and very sensitive desert environment, although a low intensity grazing land status is tabled as the minimum requirement, it is likely that this grazing land capability will need to be reduced to a wilderness or conservation land capability status i.e. soil less than 300mm deep in some instances.

The following requirements (all be they generic) should be adhered to wherever possible:

- Over areas of OPEN CAST PITS *strip all usable soil* as defined (500mm). Stockpile alluvial soils should be stockpiled separately from the colluvial (shallower) materials, which in turn should be stored separately from the overburden.

At *rehabilitation* replace soil to appropriate soil depths, and cover areas to achieve an appropriate topographic aspect and attitude to achieve a free draining landscape and as close as possible the pre-mining land capability rating.

- Over area of STRUCTURES (Offices, Workshops, Haul Roads) AND SOFT OVERBURDEN STOCKPILES *strip the top 300 mm* of usable soil over all affected areas including terraces and *strip remaining usable soil* where founding conditions require further soil removal. Store the soil in stockpiles of not more than 1.5 m around infrastructure area for closure rehabilitation purposes. Stockpile hydromorphic soils separately from the dry materials. *For rehabilitation* strip all gravel and other material places to form terraces and recycle as construction material or place in open pit. Remove foundations to a maximum depth of 1m. Replace soil to appropriate soil depths, and over areas and in appropriate topographic position to achieve pre-mining land capability and land form.
- Over area of CONSTRUCTION OF TAILINGS STORAGE FACILITIES AND HARD OVERBURDEN STOCKPILES *strip usable soil to a depth of 750 mm* 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. *For rehabilitation* strip all gravel and other material places to form terraces and recycle as construction material or place in open pit. Remove foundations to a maximum depth of 1m. Replace soil to appropriate soil depths, and over areas and in appropriate topographic position to achieve pre-mining land capability.
- Over area of ACCESS ROADS, LAY-DOWN PADS AND CONVEYOR SERVITUDES *strip the top 150 mm* of usable soil over all affected areas and stockpile in longitudinal stockpile within the mining lease area.

In general, the depth of the topsoils material for the site is between 300mm and 400mm. However, due to the shallow soil depths on the more rocky slopes outside of the alluvial gravels, and the need to rehabilitate these areas with sufficient materials to induce growth at closure, it is recommended that a minimum of 500mm is stripped from the mining and associated infrastructure areas (Sites with impacts to below the B2/1 level, or foundations that extend into the saprolitic zone (weathered rock)), and 300mm from all roads (Access and Haulage Ways) and founding pads for the soil stockpiles and TSF dumps.

The positioning of these storage facilities will need to be assessed on the basis of the cost of double handling, distances to the point of rehabilitation need, and the potential for use of the materials as storm water management facilities (berms). Suggestions include the use of materials in positions upslope of the mining infrastructure and open cast mining facilities as clean water diversion berms, and/or as stockpiles close to, but outside of the final voids that are to be created by the mining operations.

Soils removed from area that require deep foundations, lay-down pads for tailings facilities and the processing facility, dam footprints, all access and haulage roads and their associated support infrastructure must be stockpiled as close as possible to the facilities as is possible without the topsoils becoming contaminated or impacted by the operations.

The vegetated soils should be stripped and stockpiled without the vegetation having been cleared/stripped off wherever practical, while any grassland/natural veld that have been disturbed should be fertilized with super phosphate prior to being stripped (wherever practical).

This will ensure that the fertilizer is well mixed into the soil during the stripping operation and will aid in the quick cover to the stockpiles and reduce the amount of fertilizer required during the rehabilitation program. All utilization of the land for any other purpose will need to stop before mining begins.

The lower portions of the subsoils (>500mm) and the soft overburden material (where removed) can be stored as separate stockpiles close to the areas where they will be required for backfilling and final rehabilitation.

The base to all of the proposed structures to be constructed should be founded on stabilized materials, the soils having been stripped to below the topsoil contact (200mm to 300mm) and or to 500mm as the depth of utilizable soil.

It is proposed that prior to soil stripping, an appropriate (to be determined by local experts) fertilizer (super phosphate) should be added to the sandy loams and silty clay loams at a rate of about 200 kg/ha if they have not previously been fertilized. This will help to enhance the seed pool and encourage growth within the stored materials.

The stripping and handling of these very sensitive materials during the construction phase or while opening up of the open cast mining sections is highlighted, because the correct removal, storage and reinstatement of the materials will have a significant effect on the costs and the final success or failure of the rehabilitation plan at closure.

Of importance to the success and long term sustainability of rehabilitating these very sensitive environments will be the replacement of the materials in their correct topographic position, and the ability of the rehabilitation team to re-create a layer within the final profile that will inhibit vertical infiltration of water. This will be no mean feat, as the natural materials that are achieving this function at present (pre-mining and development) will have been disturbed or destroyed.

Long term and forward planning for the utilization of the materials to their best advantage and the understanding of the final "End Land Use" will need to be well understood if the optimum utilization of the materials is to be achieved. Please refer to the recommendations of materials replacement under the decommissioning and closure plan section.

The consequences of not achieving these goals will need to be assessed and quantified in terms of the long term ecological impacts, and will require the input of the specialist ecologists and engineers in formulating a management plan.

5.2 Operational Phase

Soil Stockpiling and Storage

Based on the findings of the baseline studies the sensitivity of the soil materials has been evaluated and site specific recommendations are made that are relevant to the unique conditions that pertain to a desert environment.

Table 5.2- Operational Phase – Soil Conservation Plan

Phase	Step	Factors to Consider	Comments
Operation	Stockpile management	Vegetation establishment and erosion control	Rapid growth of vegetation on the Soil Stockpiles will be promoted (e.g. by means of watering or fertilisation). 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 with storm water diversion berms to prevent run off erosion.
		Stockpile Height and Slope Stability	Soil stockpile heights will be restricted where possible to <1.5m 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 cover is essential, and should be encouraged using fertilization and induced seeding with water. 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	No waste material will be placed on the soil stockpiles.
		Vehicles	Equipment movement on to of the soil stockpiles will be limited to avoid topsoil compaction and subsequent damage to the soils and seedbank.

It is proposed that the construction of any berms needed and soil storage stockpiles are undertaken in a series of 1,5m lifts if the storage facilities are to be greater than 1,5m high. For soils that are to be stored for any length of time (greater than three years) it is recommended that all utilizable soil should be stockpiled, while the heavier subsoil's and calcrete materials should be stored as separate stockpiles. Storing the soil in this manner will maximize the beneficial properties of each material, and render them available for use at closure in the best position. Separation of these layers at the time of utilizing these soils is a matter for management, as the mixing and dilution of the soil properties is not recommended.

The utilizable soil stockpiled must be adequately vegetated as soon after emplacement on the storage pads as possible and maintained throughout the life of mining.

It is imperative, where possible, that the slopes of the stockpile berm facility are constructed to 1:6 or shallower. This will minimize the chances of erosion of the soils and will enhance the growth of vegetation. However, prior to the establishment of vegetation, it is recommended that erosion control measures, such as the planting of Vetiver Grass hedges, or the construction of benches and cut-off drains be included in the stockpile/berm design. These actions will limit the potential for uncontrolled run-off and the subsequent erosion of the unconsolidated soils, while the vegetation is establishing itself, and throughout the life of the mining operation. Vetiver is a recognised and certified natural grass specie in South Africa, and after many years of trials and testing has been given a positive record of decision as a non invasive material that can be used as a hedging grass in the development of erosion control. The advantages to the use of Vetiver Grass, is documented in the attached brochure (Refer Appendix 1 - The Vetiver Network International - www.vetiver.org).

Erosion and compaction of the disturbed soils and the management of the stored or stockpiled materials are the main issues that will need to be managed on these sensitive soil forms. This is due to the sensitivity of the soils to mechanical disturbances during/after the removal of surface vegetation and the difficulties in replacing the disturbed materials (Hardpan Calcrete and surface crusting). Although limited, the presence of the vegetation aids in the precipitation of the fine coastal mists that blow across the desert plains, and are believed to be responsible for the fine calcrete crusting, while the vegetation in tern binds and stabilises the soils ensuring some stability to the soil profile and soil retention.

These same conditions will need to be emulated if possible as soon after storage/stockpiling and/or rehabilitation of the soils has been undertaken. Although little is known or understood regarding the mechanisms involved in the surface crusting, it is evident that the formation plays a significant role in the stabilization of the desert soils

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. Care in removal and stockpiling or storage of the "Utilizable" soils, and protection of materials which are derived from the "hardpan calcrete" layer is imperative to the success of sustainable rehabilitation in these areas. The sensitivity of the soils is a factor to be considered during the rehabilitation process (Refer to section on Soil Handling and Removal – Construction Phase (5.1) and Mitigation and Management Measures – Decommissioning and Closure Section (5.3))

5.3 Decommissioning and Closure

Soil Replacement and Land Preparation

During the decommissioning and closure phase of any mining project there will a number of actions being undertaken or completed. The removal of all infrastructure and the demolishing of concrete slabs, the backfilling of open voids and the compaction of the barrier layer, and the topdressing of the disturbed and backfilled areas with utilizable soil ready for re-vegetation are all considered part of a successful closure operation.

The order of replacement, fertilization and stabilization of the backfilled materials and final cover materials (soil and vegetation) are all important to the success of the decommissioning plan and final closure.

There will be a positive impact on the environment in general and on the soils in particular as the area of disturbance is reduced, and the soils are returned to a state that can support low intensity grazing or sustainable conservation.

Table 5.3 – 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) removed during the construction phase or while opening up of open cast workings, shall be redistributed in a manner that achieves an approximate uniform stable thickness consistent with the approved postmining land use (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 soils will be analysed to determine the nutrient status 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 DWAF, on a case by case basis, before it is implemented.
			Off site disposal of soils.

Fertilizers and Soil Amendments

For any successful soil amelioration and resultant successful vegetative cover, it is necessary to distinguish between the initial application of fertilizers or soil amendments and maintenance dressings. Basal or initial applications are required to correct disorders that might be present in the in-situ material and raise the fertility status of the soil to a suitable level prior to seeding. The initial application of fertilizer and lime to the disturbed soils is necessary to establish a healthy plant cover as soon as possible. This will prevent erosion. Maintenance dressings are applied for the purpose of keeping up nutrient levels. These applications will be undertaken only if required, and only after additional sample analysis has been undertaken.

Fertilizer requirements reported herein are based on the sampling of the soils at the time of the baseline survey and will definitely alter during the storage stage.

The quantities of additives required at any given time during the storage phase or after rehabilitation has been established will potentially change due to physical and chemical processes. The fertilizer requirements should thus be re-evaluated at the time of rehabilitation.

It is recommended that a qualified person (agronomist or plant ecologist) be employed to establish the possible need or not for lime, organic matter and fertilizer requirements that will be applied, prior to the starting of the rehabilitation process.

The soils mapped are generally deficient in zinc, phosphorus, magnesium, copper and potassium. It is recommended that a standard commercial fertilizer be added to the soil before re-vegetation. The fertilizer should be added to the soil in a slow release granular form at a rate of approximately 200 kg/ha.

It will be necessary to re-evaluate the nutrient status of the soils at regular intervals to determine the possibility of needing additional fertilizer applications. In addition, it is important that only small amounts of fertilizer are added on a more frequent basis, rather than adding large quantities in one application.

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;
- ❖ Traffic should be limited where possible while the vegetation is establishing itself;
- ❖ Plants should be watered and weeded as required on a regular and managed basis;
- ❖ 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 with 200 kg/ha ammonium sulphate 4-6 weeks after germination, and
- ❖ Repair any damage caused by erosion;

Soil Sampling

During the rehabilitation exercise preliminary soil sampling should be carried out to determine the fertilizer requirements more accurately. Additional soil sampling should also be carried out annually until the levels of nutrients, specifically magnesium, phosphorus and potassium, are at the required level (approximately 20 and 120 mg/kg respectively). Once the desired nutritional status has been achieved, it is recommended that the interval between sampling be increased. An annual environmental audit should be undertaken. If growth problems develop, ad hoc, sampling should be carried out to determine the problem.

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

All of the soil samples should be analysed for the following parameters:

- ❖ pH (H₂O);
- ❖ Electrical conductivity;
- ❖ Calcium mg/kg;
- ❖ Magnesium mg/kg;
- ❖ Potassium mg/kg;
- ❖ Sodium mg/kg;
- ❖ Cation exchange capacity;
- ❖ Phosphorus (Bray I);
- ❖ Zinc mg/kg;
- ❖ Clay% and;
- ❖ Organic matter content (C %)

6. CONCLUSIONS

The Langer Heinrich Uranium Expansion Operations are planned as opencast mining operations, with the expansion of the mining operation, beneficiation (Processing, Scrubbing and Heap Leach Facilities) and disposal facilities planned to coincide and cater for the proven resource available.

Generally the survey area is characterised by a variety of sensitive soils that comprise the extremes of moderately shallow to shallow Aeolian derived desert plain soils, shallow and exposed (little vegetation) and rocky mountain slopes. The undulating to steep outcropping rocky desert contrasts with the much younger and deeper alluvial derived soils of the riverine environment that are underlain by evaporites, with a variety of transition zone colluvial soil forms that occur in between these two extremes.

All of these soil forms will be affected or impacted to some degree or other, with the open cast mining occurring predominantly in the river alluvials, and the processing and beneficiation facilities being constructed on the rockier and much shallower zones outside of the river valley. These comprise both colluvial and Aeolian derived soils. In turn, the by-product storage facilities are planned to be catered for both as backfill to the open cast mining areas, or as above ground facilities, either within some of the more prominent valleys that render themselves structurally favourable, or as a combination of these two designs.

In all cases tabled, the infrastructure and related facilities will impact to a greater or lesser extent on the materials of the site, all of which are integrately linked to the ecological well being of the existing bio-system which is very sensitive. The sensitivity of the site in general, and the soils in particular will require better than average management during the construction and operational phases if they are to be useful for rehabilitation during the later stages of the operation and into the closure phase of the project.

The current land capability is listed as wilderness in the majority of the study area, but for successful rehabilitation to take place the site will require well developed and implemented management to stabilise and re-establish the natural elements and obtain a self sustaining and stand alone land class unit.

The findings of the studies for the LHP include:

- Highly variable depth characteristics from the rocky outcrop to deeper alluvial plains;
- Generally low clay content soils with low carbon contents and resultant high erodibility;
- Poor nutrient stores in conjunction with high permeability and poor water holding characteristics;
- Highly variable grain size distribution associated with the alluvial sediments and resultant poor workability index;
- Highly sensitive capping to Aeolian deposits;
- Calcrete layer that forms the impermeable barrier to sub surface water infiltration, particularly within the riverine environ, a restrictive barrier that has ecological ramifications;
- In general, sensitive soils that will require better than average management.

If these soils are to be disturbed by the mining operation they will require a significant management input to ensure that they can be returned to an end use and stability similar to and/or better than the pre-mining environment.

LIST OF REFERENCES

Taxonomic Soil Classification System (Mac Vicar et al, 2nd edition 1991)

The Soil Erodibility Nomograph (Wischmeier et al, 1971)

Vetiver Grass for Soil and Water Conservation, Land Rehabilitation, and Embankment Stabilization – A collection of papers and newsletters compiled by the Vetiver Network – Richard G. Grimshaw (OBE) and Larisa Helfer - The World Bank – Washington DC – 1995

The South Africa Vetiver Network – Institute of Natural Resources – Scottsville – Mr. D. Hay and J. McCosh 1987 to present.

Chamber of Mines of South Africa, 1981. Guidelines for the rehabilitation of land disturbed by surface coal mining in South Africa. Johannesburg.

Department of Environmental Affairs and Tourism, 1998. Environmental impact management. Implementation of sections 21, 22 and 26 of the Environmental Conservation Act, 1989, Pretoria: Government Printer (1998).

Department of Mineral and Energy Affairs, 1992. Aide-Memoire for the preparation of Environmental Management Programme Reports for prospecting and Mining. Pretoria.

Department of Water Affairs and Forestry, 2003. A practical field procedure for the identification and delineation of wetlands and riparian areas, DWAF, Pretoria.

Non-Affiliated Soil Analysis Working Committee, 1991. Methods of soil analysis. SSSSA, Pretoria.

Soil Classification Working Group, 1991. Soil classification. A taxonomic system for South Africa. Institute for Soil, Climate and Water, Pretoria.

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).