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Biodiversity Studies at Langer Heinrich Uranium Mine, Phase 2: Biodiversity Description of the Ml140 and Epl 3500 as Baseline for Future Planning - Vegetation Map and Description (June 2009)

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Abstract

The vegetation survey was conducted over the entire ML140 and EPL 3500, comprising the Langer Heinrich Uranium operations in order to develop an understanding of the vegetation communities present and of their sensitivity to disturbance. The descriptions are intended to optimize future planning of mining operations with respect to maximum environmental protections, whilst also providing guidelines and reference conditions of the vegetation for setting restoration goals after mining operations.

The vegetation survey followed the Braun-Blanquet approach. Rainfall events prior to the survey were sufficient for the germination of most of the ephemeral plant species expected to occur in this area, whilst most of the perennial vegetation had sufficient foliage and/or flowering material to allow a positive identification. Poor knowledge still exists on many geophytes expected to occur in the area, as only remnants of these plants could be found. However, some areas had a significant amount of such plant remnants, justifying further studies in this regard. During the survey 201 plant species could be observed, of which 56 species are endemic and two species alien invasive, the latter luckily single occurrences and excluded from all data analysis. According to standard statistical projection tools, between 217 and 222 species can be expected to occur in the area, excluding the geophytes. Of the endemic species 6 are restricted endemics, known only from the Central Namib, 28 are narrow endemics, occurring only in similar habitats within the Namib, while 30 are widespread endemics, occurring over a wider variety of habitats over larger areas of Namibia. Three of the endemic species have a 'vulnerable' red list status and 17 species within the study area are protected, either by Namibian legislation only or also being listed on CITES Appendix II.

The study area falls within the Stipagrostis hirtigluma plateau-edge and inselberg vegetation type as described by Nel (1983). The vegetation found within the study area is comprised of an intrinsic mosaic of 14 plant communities, whose distribution is determined by the unique characteristics of their habitats. Each community has been fully described together with a description of its habitat. Several overarching floristic traits of the communities were used to group the communities into 5 associations; however, these associations may have similar, but *not equal habitats. It is imperative to understand that despite the often very unique habitat characteristics, the plant communities do not exist in isolation and each habitat and its community forms an integral, sometimes irreplaceable component of a rather complex ecosystem. Contributing to the uniqueness and the exceptional species diversity of the study area is the relative high capability of the landscapes to channel and retain moisture compared to the wider Namib, which is overall a water-limited ecosystem.*

Many aspects of the precise functioning of ecosystem processes and their related services remain poorly understood due to a lack of relevant knowledge (and studies). For a sensitivity rating of the plant community three aspects were taken into account: conservation value of species and habitat, the value of various ecosystem components, from the community to the species scale, to the overall functioning of the ecosystem, as well as the expected ability to restore these ecosystem components after a significant disturbance, based on available data and experience. A list of representative criteria was compiled, allocating relevant scores to specific community-, habitat- and species traits. The resultant score for a community determined whether it was rated as least sensitive, sensitive, highly sensitive or as irreplaceable. These ratings are relative to the communities found within the study area, and it is understood that they may rate much higher if viewed in a regional context, should sufficient data become available in the future. Therefore it must be understood that a 'least sensitive' rating simply implies that the overall impact on the ecosystem functioning will be least if these communities only are disturbed, it does not mean that the complete loss of such communities will be a negligible impact.

Keywords: Langer Heinrich Mine, plant communities, Braun-Blanquet, Gawib River, Namib Desert

Introduction

The Erongo Region of Namibia has long received world-wide attention due to its extensive Uranium ore occurrences. The current high price of Uranium has made it feasible for several mining companies to increase their exploration activities with the aim to start mining even low grade pockets of ore. The Langer Heinrich Uranium (LHU) Mine has only been operational since late 2005. It is situated in a constricted portion of the Gawib River System in the Central Namib, which, due to its topographically unique characteristics, forms more or less the centre of a dynamic and diverse ecosystem.

Mining at LHU is done by conventional open pit excavation, meaning that wherever ore is being found, all parts of the ecosystem will be removed as the pit is created and excavated. Apart from the pit area and infrastructure, additional sacrificial areas will be required for storing and/or dumping various types of materials:

- Tailings slurry: this needs to be spread on a relatively large, preferably flat area to enable the slurry to dry. The tailings are likely to contain high concentrations of salts and/ or minerals and may solidify into a hard and impenetrable surface, on which it will be almost impossible to establish any form of plant life. In addition, the resultant product is almost white, which does not blend in very well with the surrounding environment.

- Low Grade Ore: during the initial stage of the mine, primarily high grade ore is processed, as initial capital layouts of the mining operation need to be recovered, in addition to ongoing process costs. It is hoped that in future it will be economical to also process low-grade ore, but until then large quantities of this ore will first have to be stored.
- Waste Rock: a significant amount of material removed from the pit does not contain ore, and must be dumped. In addition to this barren materials coming from the processing plant must also be dumped.
- Top Soil: It is envisaged that the functionality of the vegetation of the actual Gawib River Bed will only be restorable if the same environment / habitat is re-created. This means that wherever new areas of the Gawib river channel are used for mining operations, topsoil should first be removed and stored until it can be used for rehabilitation, as there is no other source of such materials within the mining license.

The placement of these materials requires careful consideration of the rather complex ecology of the LHU mining area. Information regarding plant species and their distribution in the core area of the LHU mine was collected during the original environmental Impact Assessment (EIA) process in 2004. However, judging from the plant list compiled then, as well as the representative photographs, rainfall preceding that survey was not sufficient to allow the majority of the plant species to grow, neither did several perennial species have sufficient foliage to be correctly identified. Hence, plant groups could only be described on a rather coarse level, which does not give too much information about the complex habitats, thus also limiting the use of that information for rapid management decisions at the scale of the currently active mine.

Since the 2004 EIA survey, mining activities have significantly altered the Gawib River channel. Despite this, and due to the large rainfall events during 2008, enough vegetation remained, re-sprouted and germinated on adjacent habitats – small runoff channels and slopes north and south of the mine, to allow a more detailed description of the vegetation of the core area. It is envisaged that this more detailed description will aid the ecologically optimal placing of permanent dump sites required within the coming year. After that, a wider vegetation survey, covering the entire mining license area (Phase 2), will have to be conducted in order to guide decision making when mining expands into the other areas of the ML.

Scope of study

The aims of this study were to:

1. Conduct vegetation surveys in the designated study area (approximately 2.5km by 400m)

2. Develop a vegetation map made up of two layers, namely a landscape types / broad habitat map and a finer scaled vegetation community map that can overlay the landscape type map.
3. Compile a vegetation sensitivity map that can overlay the vegetation map.
4. Compile a report that describes the various landscape and community types, outlines plant species found in the various communities, describes the basic ecosystem dynamics of these communities and outlines why some areas are more sensitive to disturbance than others.

Study area

Surveys for this study (Phase 1) concentrated around the present core mining area (Figure 1); the latter is approximately 400 m wide and 2.5 km long. The edge of the schist outcrops, on which the NamWater Reservoirs are situated, were taken as the western limit of the survey, whilst the current explosives storage area was taken as the eastern limit of the study.
The area is situated in the narrowest section of the Gawib River system, which has its catch-

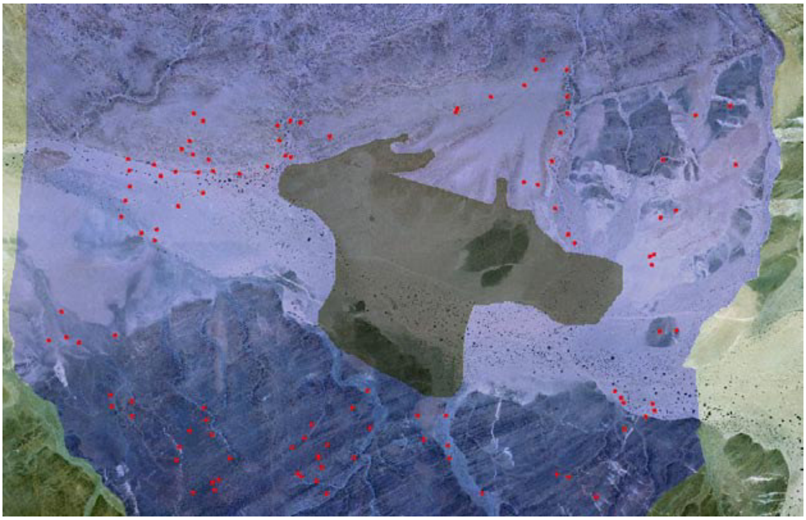


Figure 1: *Outline of the study area (blue overlay) around the approximate current mining area (black overlay). Also indicated are the actual survey sites of the vegetation survey (red dots).*

ment eastwards up to the Tinkas watershed. To the west of the study area the Gawib River opens up and drains in a northerly direction into the Swakop River. To the north, the study area is bordered by moderate to steep slopes of quartzite boulders of the Langer Heinrich Mountain, and also conglomerate deposits of old valley-fills. To the south, the Gawib River is bordered by biotite schist outcrops and ridges of the Schieferberg. Several tributaries reach the Gawib River within this short stretch from both northern and southern slopes. The river valley itself is a mixture between floodplains and deep sandy flood channels. The distribution of vegetation is strongly influenced by topography – steepness and aspect of the substrate. Surface texture – understood here as size and amount of boulders, pebbles and gravel as well as the physical nature of the substrate (geology) further determine soil type and depth and its moisture regime, and thus also the types and number of micro-habitats available for plant establishment.

Previous Work

A vegetation survey of the mining area was conducted during the original EIA in 2004 (Friend 2005). Vegetation was not as abundant during that period as during the current survey. For the current study area, only 8 broader plant communities could be described and delineated during the EIA. This already highlighted the higher species diversity of the northern slopes, but information to guide decisions on dumping sites on the southern slopes was limited.

Prior to the EIA, several studies had been conducted in the Central Namib Desert, but little of this information was available on the current study area. Popular floristic guides on the flora of the Namib Desert have been published (e.g. Burke 2003), but these only list the most conspicuous and/or commonly found species, without specific information on locality. Robinson (1976) described several communities for the Central Namib, but never produced a vegetation map or any detail of the localities of his vegetation types, nor is his original data available. Hachfeld (1996, 2000) did an extensive, but low-density survey of vegetation throughout the Central Namib. Her data is available from the NBRI, but only 2 of her relevés fall within the current study area – both of the riverine vegetation. Nel (1983) studied the availability and quality of fodder on the plains of the Central Namib, including the study area. He also provides a very rough description of the vegetation types of the Central Namib, in which he classifies the entire study area as part of the *Stipagrostis hirtigluma* plateau-edge and inselbergs. He further stated that this area was an important habitat for mountain zebra, while oryx, kudu, springbuck and ostrich occurred sporadically.

For the immediate purpose of providing a more accurate decision-making tool to guide the selection of sites for a new tailings facility, as well as rock-dumps, there was thus a clear deficit of available vegetation data.

Materials and Methods

Field Survey

Surveys were conducted according to the Braun-Blanquet approach (Mueller-Dombois and Ellenberger, 1974). A total of 110 sites were surveyed each comprising of a 20 x 25 m plot randomly selected across different terrains within the study area. For each site the estimated canopy cover of all species was recorded, also paying attention to the different layers (height-classes) of the species. Additionally, notes were taken on abiotic characteristics that could have a major influence on species survival or distribution, e.g. slope and substrate. These notes were used to derive the major habitat types. Specimens were collected for the majority of the plant species, to verify their identification. For every survey site a GPS reading was recorded, and a representative photo taken. The actual data derived from a survey site and used further for data analysis is referred to as a relevé.

Identification

Specimens were identified at the National Botanical Research Institute (NBRI) of Namibia, following the NBRI's latest use of nomenclature. The entire collection was submitted to the NBRI. Common names, where available, were derived from Burke (2003), Coates Palgrave (2002) and Klaassen and Craven (2003).

Mapping and GIS

Landsat images for the area from April 2000 and April 2005 were supplied by the Ministry of Agriculture, Water and Forestry. These images have a resolution of 30 x 30 m, which is relatively coarse for the small study area. Both images were segmented into polygons with similar reflectance, using the Definiens (e-Cognition) software. The Landsat image from 2000 appeared to yield the more realistic segmentation, as the 1999/2000 rainfall season was also relatively good in the area (Hachfeld 2000). Next, the locations of all survey sites were projected onto these segments, assigning each site to its respective association or community. The aim of a supervised classification of a satellite image is that it uses the reflectance-values of these sample sites (each assigned to a specific habitat-, vegetation- or community-type) to then classify segments with similar reflectance values as the. However, due to the very high level of ground reflectance and low resolution, no satisfactory image classification could be obtained, and could not be used further for this study. Such classification, in particular for a desert environment with a complex landscape but sparse vegetation, is best done when the image is taken as close as possible to the ground survey. Images with a higher resolution will be more suitable.

Thus, to map the approximate outline of the communities studied, a high resolution aerial photograph was used. The survey sites were projected onto this image. Based on observations during the survey, approximate outlines of the plant communities were digitised by hand, using Arc View. This approach was only possible due to the small size of the study area and the relatively detailed survey thereof, it will not be possible to map a larger area with such methodology.

For database purposes, the GPS positions of all survey sites, as well as a photo of all survey sites were submitted to the GIS specialist.

Data analysis

All data was entered into TurboVeg (Hennekens 1996, Hennekens and Schaminée 2001), which is used as a database by most larger botanical research institutes throughout the world, including the Namibian National Vegetation Survey of the NBRI (Strohbach 2001, and available from the NBRI). From there, data was exported to Juice (Tichý 2002), and classified using weighted TWINSPAN divisive clustering. Vegetation units are most commonly described as associations, which can be further divided into communities. Such associations and communities are defined based on a group of species of which at least 50% occur in every relevé belonging to that community or association. It may, however, also occur that within an association a community is defined in which a group of species it totally absent. Associations usually contain one to several differential species that are either totally absent or at the most present in low numbers in less than 20% of the relevés not allocated to that association (Barbour *et al.* 1999). Thus, some species are common throughout a study area, whilst other species do occur throughout the study area as well, but are typically denser and vigorous in certain habitats, one such example is *Commiphora saxicola*. Other species may be entirely restricted to a specific substrate or habitat, e.g. *Aloe namibensis* or *Acacia erioloba*, whilst other species may be restricted to a specific type of habitat, but variable geology, e.g. *Euphorbia virosa*, found on both schist and quartzite slopes.

Conservation status of species was derived from Craven *et al.* (1999), Gibbs Russell *et.al.* (1990), Golding (2002) and Loots (2005).

Results

Description of the different habitats

Habitats were identified from the vegetation perspective, paying attention to type and depth of soil, surface texture (size and amount of stoniness), niche availability and inferred moisture retention capability of the larger area. Within habitats, slope and aspect of the slope will create many more micro-habitats and niches. The approximate delineation of these habitats is shown in Figure 2.

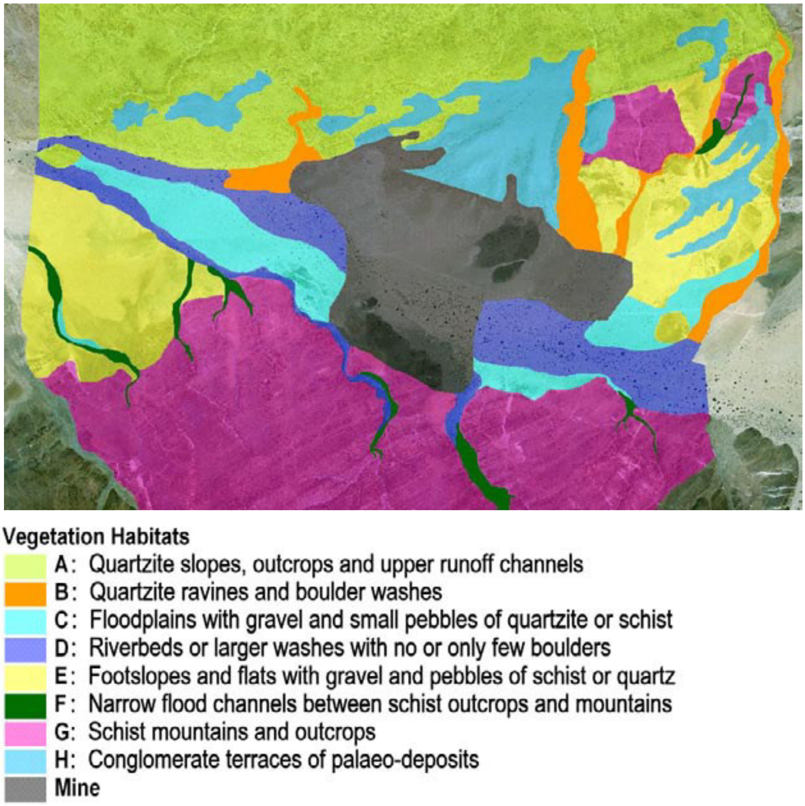


Figure 2: *Approximate delineation of the different vegetation habitats identified.*

A: Slopes, outcrops and runoff channels on quartzite

Location: bordering the Gawib River to the northwest of the current mining area, and then extending north and east as part of the Langer Heinrich Mountain.

This habitat has a relatively steep but varied topography with a very coarse surface texture, ranging from rock faces and boulders to pebbles and gravel. Accordingly, soil depth is very varied. Soils here accumulate in pockets on shallower areas and in runoff channels or rock-crevices. Similarly, moisture from occasional precipitation events will accumulate in crevices, runoff channels and soil pockets, where it may be protected from evaporation for considerable periods. Hence these slopes offer a wide variety of niches for plants to become established. Despite sporadic rainfall events, the moisture regime is relatively favourable, as can be seen in the high diversity of perennial plant species present on these slopes. Seeds of ephemeral species will also accumulate here, but will only grow for a short while after sufficient rains.

B: Ravines and boulder washes on quartzite
Location: northwest and northeast of the current mining area, towards and just below runoff channels from the Langer Heinrich Mountain.

The deep ravines channel vast amounts of runoff from the Langer Heinrich Mountain after large rainfall events, occasionally also with eroded material (boulders, sand), which are deposited just below the ravines in broad washes that drain into the Gawib River channel itself. The ravines are relatively narrow and steep, protecting water from rapid evaporation and thus helping maintain surface water for variable periods of time after a rainfall event. Seepage of water into the lower sandy soil-layers and rock crevices enables the persistence of species such as *Ficus cordata* (rock fig), which prefer to grow near water. Likewise, a favourable water regime in the boulder washes creates a habitat for a high diversity of shrubby perennial vegetation, which is complemented by an equally high diversity of ephemeral plant species after rainfall events. This habitat is most likely an important resource area for fauna as well.

C: Gravelly floodplains with mixed substrate
Location: in discontinuous patches adjacent and between the active flood channel of the Gawib River, spanning from east to the west of the core mining area.

The floodplains will only be flooded during extreme rainfall events. Soil depth and material is variable, but is covered with a 'spongy' mulch of gravel. These floodplains do not have a very favourable moisture regime, as can be seen from the low and patchy density of perennial vegetation. However, these plains can absorb quite a bit of moisture during rainfall events due to the porosity of the upper soil. Accordingly, dense stands of ephemeral vegetation can establish on these floodplains after rains, and their seeds get trapped in the soft sands between the gravel. Loss of this functionality due to compaction by vehicles (Figure 3) will result in more rapid runoff and thus loss of moisture and vegetation from the ecosystem.

Figure 3: *Excessive tracks on the gravelly floodplains. In all areas that fall outside the ore deposits, such tracks must be kept to an absolute minimum.*

D: Flood channels of the Gawib River

Location: wider, meandering river channels originating east of the mine, larger tributaries from north and south of the current mine, and running through the mine to continue westwards.

The soils are deep coarse sands, occasionally with a high amount of gravel. These sands absorb moisture quickly, and can retain a substantial amount of moisture in the deeper layers, while a large amount of moisture will seep into the groundwater. Within a desert-environment, this is the portion of the Gawib system with the most favourable moisture regime, enabling the establishment and persistence of large trees. The above-ground distribution of these trees appears sparse; however, their below-ground root systems occupy a soil and water reserve far exceeding their canopy area. These trees and associated shrubs create 'islands of fertility' in the desert, providing a suitable habitat for numerous other plants, accumulating sparse litter and thus also creating a rich environment for various types of fauna. Apart from that, the extensive root systems of the vegetation here stabilises the soils to some degree, and acting as a trap for more soils as well as seeds and debris from higher up, which would otherwise be lost from the system. Although these flood channels are very dynamic and can change drastically after a flood-event, the creation of this habitat – accumulation of eroded sands and the slow growth of the large trees – means that this habitat may be one of the most difficult to recreate without at least conserving every possible patch and storing the sandy soils of areas that will be excavated in future.

E: Gravel footslopes and associated small, shallow washes

Location: below eroded conglomerate terraces north-east of the mine, also in discontinuous patches just north of the schist outcrops of the Schieferberg west of the current mine.

The soils are relatively shallow, of mixed substrate, and covered with a dense layer of gravel and coarser pebbles. The steeper the slopes, the more gully erosion occurs; this is most conspicuous towards the east of the current mine. This is not a very favourable habitat for plant life. Perennial plants are concentrated towards the shallow washes, while the remainder of the footslopes only has a low diversity of short-lived ephemeral vegetation.

F: Narrow flood channels between the schist outcrops of the Schieferberg

Location: major tributaries of the Gawib river coming from the schist outcrops south and southwest of the current mine area.

Soils are fine-grained and thus dry out more rapidly, whilst soil depth varies between boulders and pebbles present in the flood channel. Moisture retention is thus much lower than in the Gawib river itself, which is reflected in the smaller size of trees found here (although they may be of equal age as in the Gawib River). However, this habitat is suitable for the low shrubs that are found in high densities in these tributaries. These shrubs again accumulate a lot of seeds and debris. Frequently observed and relatively fresh tracks of larger mammals indicate that these tributaries may be important corridors for animal movement.

G: Schist slopes, ridges and steeper runoff channels
Location: this is the Schieferberg south of the current mining areas, as well as smaller schist outcrops northeast of the mine.

Soils are generally very shallow and fine-grained, unable to retain much moisture. The surface texture is as rough and varied as the quartzite slopes (habitat A), yet the physical nature of the schist does not allow the same amount of water-accumulation, making this a much drier environment. Added to this, the dark colour of the substrate absorbs much more light-energy, leading to higher surface temperatures, which negatively impact on plant life. Not surprisingly, most perennial vegetation is concentrated towards steeper slopes and runoff channels, with single individuals present on the exposed, flatter ridges. Most of the perennial vegetation here has an ability to store water in their thick, fibrous or succulent stems. A high density of short-lived ephemeral plants may establish after sufficient rains, otherwise these outcrops are relatively bare.

H: Conglomerate terraces as remnants of old valley-fill deposits
Location: these occur in pockets south of the Langer Heinrich Mountain, directly north and northeast of the current mine pit. Some remnants of this deposit can also be found on top of the lower quartzite ridges northwest of the mine.

Soils are relatively shallow, occasionally small pockets of wind-blown sand do occur and support a denser stand of grasses. Typical is a large amount of quartz pebbles, under which fenster-algae can be found. Perennial vegetation is sparse and more concentrated towards the upper ends of runoff channels (which erode away lower down to expose quartzite slopes). A low and patchy but relatively stable grass layer is present on these ‘plateaus’, which may explain the high number of animal paths on these areas.

Overview of plant communities
An overview of the different plant communities, their associations and their habitats is given in Table 1. In addition, the conservation status and sensitivity rating of the different plant communities is also listed, according to the amount of species recorded, the conservation status of those species as well as their rate of establishment and growth until they reach sizes presently observed. For each species, more details are given in Appendix 1.

Table 1: *Overview of habitats and the plant associations and communities found in the current Langer Heinrich Core Area.*

Habitat	Description	Vegetation association	Community	Conservation status	Notes
A	Quartzite slopes, outcrops and upper runoff channels	*Monechma cleomoides – Hermannia helianthemum* sparse shrublands	1: *Commiphora* species – *Aptosimum lineare* quartzite slopes	86 species recorded 1 vulnerable endemic species 4 protected species 27 endemic species	many slow-growing shrubs many suitable niches for continued regeneration and persistence of plant populations **Sensitivity: 4**
B	Quartzite ravines and boulder washes		2: *Sterculia africana – Enneapogon scoparius* ravines	69 species recorded 3 protected species 22 endemic species	slow-growing shrubs and trees high potential for water to accumulate and remain available for the ecosystem for prolonged periods after a rainfall event **Sensitivity: 4**
			3: *Petalidium variabile – Stipagrostis hochstetteriana* boulder washes	112 species recorded 1 vulnerable endemic species 6 protected species 36 endemic species	community with highest species diversity many slow-growing trees and shrubs dynamic system, but with many suitable niches for continued regeneration of perennial and annual vegetation facilitates re-distribution and storage of runoff from higher areas **Sensitivity: 4**
C	Floodplains with gravel and small pebbles of quartzite or schist	*Calicorema capitata – Hermannia solaniflora* sparse shrublands with low trees	4: *Salsola tuberculata – Stipagrostis obtusa* gravel plains	36 species recorded 2 protected species 12 endemic species	relatively dynamic system, many annual species compaction of the topsoil by vehicle tracks will reduce infiltration of water, leading to a loss of water from the system during scare rainfall events, whilst accelerating erosion in adjacent river channels **Sensitivity: 2**

Habitat	Description	Vegetation association	Community	Conservation status	Notes
D	wider and relatively level riverbeds / washes with no or only few boulders		5: *Acacia erioloba – Zygophyllum stapffii* washes with sand and gravel	44 species recorded 1 protected species 16 endemic species	relatively dynamic system slow-growing trees facilitates re-distribution and storage of runoff from higher areas **compaction of topsoil by vehicle tracks should be avoided or minimised** **washes off schist mountains may not be blocked off** **Sensitivity: 3**
			6: *Acacia erioloba – Stipagrostis damarensis* sandy washes	82 species recorded 3 protected species 26 endemic species	many large specimens of very slow-growing trees relatively dynamic system, depends on run-on and seepage of moisture from higher-lying areas for continued function **identify areas that must be mined and restrict impact to those areas, retain key patches intact** **Sensitivity: 3**
E	footslopes and flats with gravel and pebbles of schist or quartz	*Stipagrostis obtusa – Aizoanthemum rehmannii* sparse grasslands	7: *Zygophyllum simplex – Monechma desertorum* schist footslopes	29 species recorded 12 endemic species	very dynamic system – mainly annual species relatively wide occurrence of species within Central Namib **Sensitivity: 1**
			8: *Adenolobus pechuelii – Commiphora saxicola* quartzite footslopes and small washes	44 species recorded 2 protected species 16 endemic species	relatively dynamic system, mostly annual species with low/patchy distribution of slow-growing shrubs most species should be able to regenerate fairly quickly from stored topsoil **Slow-growing shrubs and protected species should be relocated should the area be used for mining activities** **Sensitivity: 2**

Habitat	Description	Vegetation association	Community	Conservation status	Notes
F	narrow flood channels between schist outcrops and mountains, with schist gravel and/or boulders	*Zygophyllum stapffii – Sesamum marlothii* riverine shrublands	9: *Zygophyllum stapffii – Sesamum marlothii* riverine shrublands	50 species recorded 1 protected species 17 endemic species	very dynamic system important link of runoff from higher areas transported to lower-lying areas **Sensitivity: 3**
G	schist mountains and outcrops – upper ridges/rests and shallower slopes	*Trianthema triquetra – Stipagrostis hirtigluma* sparse grasslands	10: *Enneapogon desvauxii – Euphorbia phylloclada* schist ridges	31 species recorded 3 protected species 13 endemic species	dynamic system of annual species with solitary specimens of unique succulents and shrubs **Solitary succulents and shrubs can be relocated** **Sensitivity: 1**
			11: *Petalidium canescens – Commiphora saxicola* schist slopes and small runoff channels	41 species recorded 1 protected species 16 endemic species	perennial vegetation mostly clustered around upper and steeper edges of runoff channels good regeneration of *Commiphora saxicola* noted **Use of the area should exclude the higher edges of runoff channels, or should be restricted to one area only, and specimens relocated** **Sensitivity: 2**
H	Conglomerate terraces of palaeo-deposits		12: *Eragrostis nindensis – Trianthema triquetra* conglomerate flats and upper slopes	40 species recorded 1 protected species 12 endemic species	very dynamic and patchy system steeper areas are prone to gully erosion and have lowest sensitivity flatter areas create runoff that is collected in the more diverse upper quartzite runoff channels **Disturbance should be limited to the outer slopes of the system, else restricted to one part of the system, relocating the shrubs that are found on areas where runoff collects** ***Eragrostis nindensis* can be an important fodder plant during periods of prolonged drought** **Sensitivity: 2**

Sensitivity ratings:
- 1: least sensitive or of least concern
- 2: sensitive – mitigation measures to be implemented
- 3: highly sensitive – minimise disturbance as far as possible
- 4: NO GO area – very high conservation and ecological value

Explanation of sensitivity ratings used

Four sensitivity categories have been used, and are defined as follows:

1: Least sensitive or of least concern

Criteria: relatively low availability of niches that are favourable for plant persistence, overall low species diversity, dominated by ephemeral plants, few or no perennial plants, and the habitat or growth conditions can be re-created to some degree, low conservation status. In addition, loss of such areas will not have a major detrimental impact on the functionality of surrounding ecosystem components.

Management implications: areas where such communities occur should be looked at first as sites for permanent dumps. It may be possible to re-create some ecological functionality of such dumps by landscaping and matching soil surface conditions to resemble the original. The area will need to be scouted prior to preparation for dumping, to remove perennial plants where necessary, possibly also look for bulbous plants on lower-lying areas by searching through topsoil.

2: Sensitive – mitigation measures need to be implemented

Criteria: moderate but patchy availability of niches suitable for plant persistence, moderate species diversity, may be very patchy due to a localised amount of suitable niches, low conservation status, but the available niches will be difficult or impossible to re-create.

Management implications: most of the areas where such communities occur are adjacent to areas that are more sensitive. Should such area be needed for mining operations, efforts should be made to utilise only some of these areas so that similar areas are made available as habitat for transplanted plants. Ideally, planning should be done for the entire life-of-mine, before such areas are sacrificed. This will ensure that the smallest area possible is sacrificed.

3: Highly sensitive – minimise disturbance as far as possible

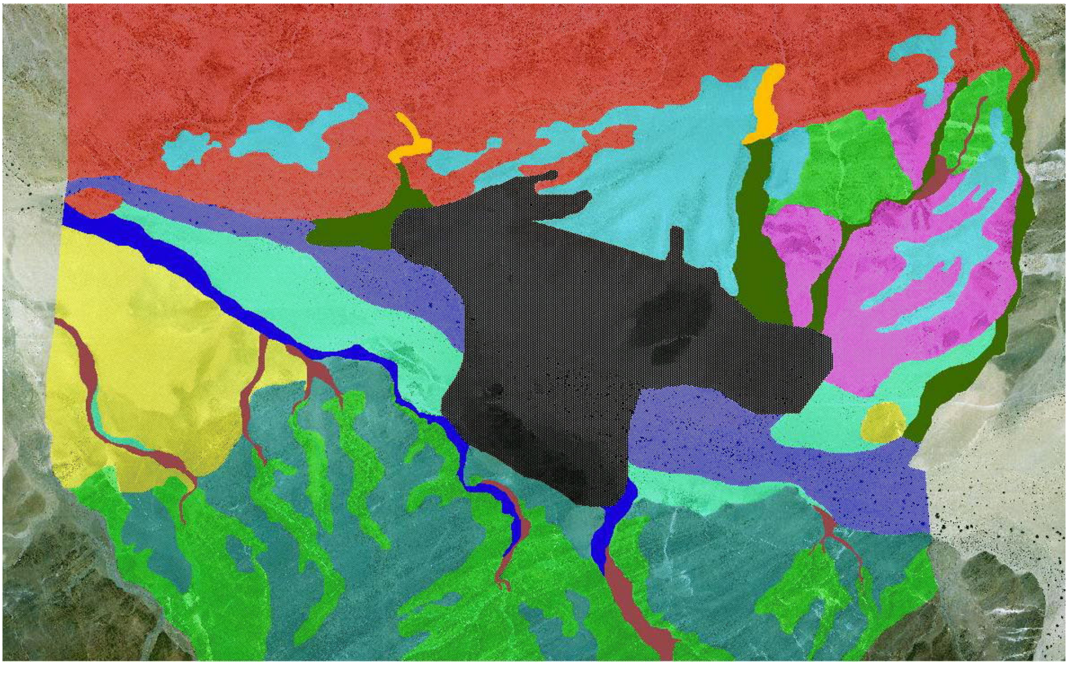
Criteria: high diversity and number of plant-favourable niches, moderate to high species diversity, moderate conservation status. Many very slow-growing trees and shrubs are present in these areas. Habitat difficult to recreate once disturbed unless properly planned. Further, some aspects of this community play a central role within the entire Gawib ecosystem.

Management implications: Disturbance should only be allowed in these areas, where absolutely necessary, in this case only if sufficient ore has been identified below such communities. Even then, disturbance should be kept to a minimum. Key areas, e.g. patches of relatively dense trees should be demarcated as definite no-go areas, which should also not be disturbed by vehicle tracks or other side-line mining activities (e.g. construction of buildings). If these areas are disturbed, some patches must be left intact and sufficient amounts of topsoil should be stored from disturbed areas. Research on the regeneration and establishment potential of plants species affected shall need to be initiated as soon as possible to assist with restoration planning.

4: NO GO area – very high conservation and ecological value
Criteria: high species diversity, high conservation status, availability of many diverse niches for fauna and flora, habitat difficult or impossible to re-create once disturbed.

Management implications: areas where these communities are found occur on the absolute fringes of ore body and outside the ore deposits. There is thus no justification to disturb these sites. This also means that vehicle tracks and any kind of pollution must be prevented and possible impacts from slow-falling dust after blasts are minimised.

Description of Plant Communities
Below follows a brief description of the communities found within the eight habitat types described and discussed above. The descriptions focus on species differentiating the individual communities. A detailed synoptic table listing all species of each community, as well as their frequency within a community and their fidelity value (indicating ecological significance) is given in the Appendix, together with a summary of this synoptic table, listing the constant and dominant species for each community. This list thus also provides an insight into other species commonly found in each community, which may also be common throughout the study area. The approximate delineation of the communities is shown in Figure 4.



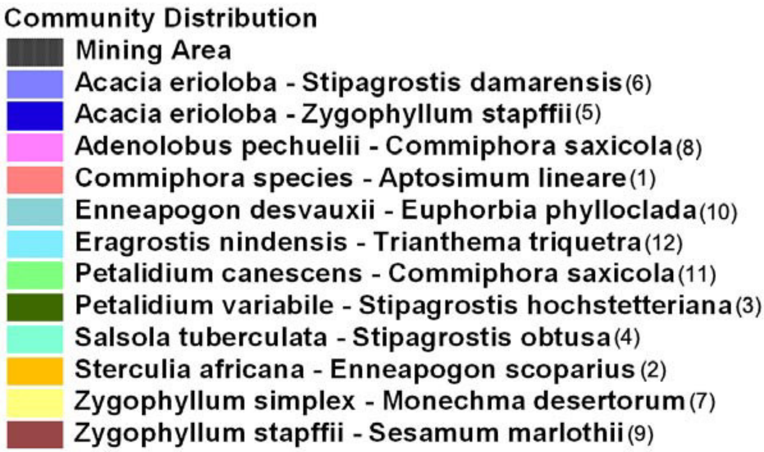


Figure 4: Distribution of the different plant communities identified from the survey data.

The *Monechma cleomoides – Hermannia helianthemum* association is subdivided into communities 1, 2 and 3 that occur on rough quartzite substrates. These communities consist of very patchily distributed low trees, higher shrubs as well as a large diversity of low semi-woody (suffrutex) shrubs. Total diversity will vary according to available moisture every year, trees and shrubs are complemented with a wide variety of short-lived perennial forbs as well as several ephemeral herbs.

2004 EIA: Communities 1, 2 and 3 were included in the *Commiphora* species – *Peliostomum viscosum*, and *Calicorema capitata – Monechma cleomoides* communities in the previous EIA.

1: *Commiphora* species – *Aptosimum lineare* community

The quartzite slopes and ridges (habitat A) to the northwest of the current mine, and extending east as part of the Langer Heinrich Mountain slopes, support a very high diversity of plants, also many perennial species. The most significant and well represented species found here is the succulent *Aloe namibensis* (Namib Aloe), which is endemic to the Central Namib, and regarded as vulnerable. The community is typified by many large specimens of *Commiphora glaucescens* (blue-leaved Commiphora), *Commiphora virgata* (slender or twiggy corkwood), and occasional specimens of *Sterculia africana* (tick tree), all low trees or shrubs with swollen, fibrous stems that can store water.

Other shrubs include *Boscia foetida* (smelly shepherd's tree) and *Euphorbia guerichiana* (paper-bark woody Euphorbia). A fair amount of nutritious grasses such as *Antephora pubescens* (wool grass), *Eragrostis nindensis* (eight-day love grass) and *Stipagrostis ciliata* (tall bushman grass) can be found on the slopes. Also conspicuous is the high diversity of sub-shrubs, most conspicuous are *Aptosimum lineare, Monechma cleomoides* (Namib perdebos), *Hermannia helianthemum, Petalidium variabile* (variable Petalidium), *Tephrosia monophylla* (single-leaved Tephrosia), *Barleria lancifolia* (blue Barleria) and *Zygophyllum cylindrifolium.*
The composition and density of plants in this community at specific sites is very variable, depending largely on the steepness and aspect of the slope. The overall high species diversity, as well as high number of endemic and protected species present, renders this community the highest sensitivity rating: 4.

2: *Sterculia africana – Enneapogon scoparius* community

Short but steep and narrow ravines (habitat B) have been eroded into the quartzite just northwest and northeast of the current mining area. Although these areas are relatively small, the short term availability of surface water in perched rock-pools, as well as a significant amount of subsurface moisture, makes these rather unique microhabitats for both flora and fauna. Here we find the rock fig, *Ficus cordata*, which will not be able to establish in any other habitat in the desert, as well as delicate herbs such as *Jamesbrittenia* species, and the sub-shrubs *Abutilon pycnodon, Camptoloma rotundifolium, Amphiasma divaricatum, Anticharis imbricata, Barleria merxmuelleri* and *Dyerophytum africanum* (desert statice). Further characteristic low trees are *Sterculia africana (tick tree)* and *Commiphora glaucescens*. Palatable perennial grasses found here are *Antephora pubescens* and *Enneapogon scoparius* (bottle-brush grass).
Similar to community 1, this community gets a sensitivity rating of 4, attributed to its high species diversity, high number of endemic species and uniqueness of habitat within a desert environment.

3: *Petalidium variabile – Stipagrostis hochstetteriana* community

Wherever occasional, fast-flowing floodwaters discharge onto more level ground below ravines or quartz slopes, they have also, over time, deposited large round boulders and deep sands (habitat B). This community is then found just below community 2 described above, as well as in the washes between the schist outcrops northeast of the mine. It is characterised by a high but variable density of high shrubs such as *Calicorema capitata* (grey desert-brush), *Commiphora virgata* and *C. glaucescens*, *Boscia foetida* and the sub-shrubs *Monechma cleomoides, Ruellia diversifolia, Asparagus pearsonii, Hermannia helianthemum, Petalidium variabile* and *Tephrosia monophylla*. *Stipagrostis ciliata* and *Stipagrostis hochstetteriana* (Gemsbuck tail grass) are common perennial grasses. These washes also host a wide variety of ruderal (weedy) annual species, of which the composition and density will change every year, according to rainfall events.

In these washes, the large boulders prevent perennial species from being washed away by flash-floods, whilst also trapping a large amount of debris and seed-material. It is thus not surprising that this community had the highest species diversity, including the highest number of endemic species. Although this community will be very dynamic – easily changed by occasional flash-floods, very patchy plant distribution and very variable amount and density of annual plants – it remains a very important source area for seeds to be trapped, regenerated and re-distributed. This community thus has a sensitivity rating of 4, and all available patches of this community should be preserved as far as is possible.

The *Calicorema capitata – Hermannia solaniflora* association is subdivided into the communities 4, 5 and 6 that are found on open floodplains and flood channels of the Gawib River itself.
2004 EIA: communities 4, 5 and 6 were incorporated into the *Calicorema capitata – Zygophyllum stapffii* rocky river terraces, *Calicorema capitata – Monechma cleomoides* washes and *Acacia erioloba – Stipagrostis damarensis* (referred to as *S. namaquensis*) riverbeds. Although the descriptions are very similar, these communities could be described and regrouped more efficiently, thus also changing the delineation of occurrence.

4: *Salsola tuberculata – Stipagrostis obtusa* community

This community is restricted to the floodplains (habitat C) adjacent to the sandy flood channel of the Gawib River. The most constant shrubs here are *Calicorema capitata* and *Salsola tuberculata*, with occasional stands of the grass *Stipagrostis ciliata*. After sufficient rains, as during the survey, a high number and density of annual plants can be found here, most commonly the grass *Stipagrostis obtusa* (small bushman grass) as dominant species, interspersed by *Stipagrostis hirtigluma* subsp. *hirtigluma* (Bloutwa), and the herbs *Hermannia solaniflora, Heliotropium oliveranum, Helichrysum candolleanum* and *Sesuvium sesuvioides* (desert pink). Occasionally *Acacia erioloba* (Camelthorn) or the shrub *Commiphora saxicola* (rock corkwood) can be found here.
Overall species diversity is relatively low, but may vary dramatically between seasons. Yet it remains an important albeit temporary resource area for fauna, whilst also not being isolated in its functionality within the ecosystems (see habitat description), thus has a sensitivity rating of 2.

5: *Acacia erioloba – Zygophyllum stapffii* community

This community is found on the lower, wider tributaries to the Gawib River, often with a fair amount of schist gravel and fine schist-derived soils, south and west of the current mine (habitat D). *Acacia erioloba* is a conspicuous but sparse tree here, but usually much smaller than their counterparts in community 6. The community is also characterised by low to moderate density of the shrubs *Calicorema capitata* and *Zygophyllum stapffii* (dollar bush), with the latter often becoming dominant, and moderate stands of the perennial grasses *Stipagrostis schaeferi* and *S. ciliata*. Further, a variety of ruderal annual species may be found, their density and diversity changing every year.

Although species diversity is moderate, this community forms an important link between upstream runoff of water and seeds, and lower-down resource deposition. Where this community occurs on the lower fringes of the tributaries off Schieferberg just south of the mine, many tracks of animals have been observed, thus also emphasizing that these 'resource pathways' should not be cut off by mining activities, and thus has been given a sensitivity rating of 3. West of the mine, *Acacia erioloba* trees are bigger and denser, but will probably make way for excavations in the future. Here it would be desirable to store adequate topsoil, to enable a habitat re-creation and gradual regeneration after mine closure, fed by runoff from higher-lying areas.

6: *Acacia erioloba – Stipagrostis damarensis* community

This community is found on the deep sands that have accumulated in the flood channel of the Gawib River (habitat D). The most conspicuous element of this community are large trees of *Acacia erioloba*, in varying density, also with *Maerua schinzii* (ringwood tree), *Euclea pseudebenus* (false ebony), *Parkinsonia africana* (green hair thorn) and the waxy-leaved shrub *Salvadora persica* (mustard tree). *Stipagrostis damarensis*, as well as *S. schaeferi* and *S. ciliata* are the most important perennial grasses, whilst the annual grass *Brachiaria glomerata* is also characteristic of this community. The above perennial species are the most constant feature, but are complemented by several other shrubby and many herbaceous species. The density and species composition of this community varies enormously, and will also do so from year to year, but species diversity is relatively high, with a large number of endemic species as well.

The community has a sensitivity rating of 3, as most of the tree species present here depend on the deep soils and moisture regime only found here, to be able to grow vigorously. Also, many of these large trees are most likely hundreds of years old, meaning that should all of this habitat be destroyed, it will be almost impossible to re-create it. These large trees also create important micro-habitats for an array of other plant species, accumulate litter and also create a special habitat and resource for a variety of fauna. Unfortunately a large expanse of this community occurs exactly over the ore, which means that all patches of this community that fall just on the outer fringe or outside the identified ore body (e.g. adjoining the quartzite ridges northwest of the mine), should be strictly protected and treated as a sensitivity 4 zone.

It will also be imperative that topsoil of this community be stored, otherwise re-creation of the habitat may be impossible. During a survey a fair number of seedlings of *Acacia erioloba* were observed, together with many seedlings of other low shrubs. It would be useful for future habitat re-creation to select some sites with such seedlings, permanently demarcate the area and monitor the progress and/or survival of these seedlings over the coming years.

The *Stipagrostis obtusa – Aizoanthemum rehmannii* association is subdivided into communities 7 and 8 that grow on low gravelly footslopes. Gravels are schist, quartz or quartzite (habitat E).
2004 EIA: These communities were incorporated into the *Calicorema capitata – Monechma cleomoides* washes and schist and quartz gravelly footslopes and terraces in the previous EIA.

7: *Zygophyllum simplex* - *Monechma desertorum* community

This community is most prominent on the low undulating plains off the schist outcrops west of the mine, south of the Gawib River. Smaller patches of this community occur east of the mine as well, and may extend further east into the mining area (to be surveyed during Phase 2). Only very few and sparse perennial shrubs occur, such as *Commiphora saxicola* and *Calicorema capitata*. The bulk of the plant species found here are short-lived ephemerals. The grasses *Stipagrostis ciliata* and *S. hirtigluma* subsp *hirtigluma* are often the dominant species during favourable seasons. The most conspicuous of these ephemerals is *Aizoanthemum rehmannii*, *Sesuvium sesuvioides, Monechma desertorum* and *Euphorbia phylloclada*. A fair number of remnants of bulbous geophytes have been observed here, but species could not be identified. Overall species diversity is, relative to the study area, very low, but needs further studies to identify the geophytes. During dry years these low footslopes may remain bare.
This is one of the few communities with a sensitivity rating of 1. However, it would be advisable to remove at least some portion of the topsoil (about 25-30 cm) prior to any dumping, and remove bulbs from this topsoil. Bulbs can easily be grown in a nursery for later relocation, and this will also provide ample opportunity to properly identify them, as geophytes are in general poorly studied in Namibia.

8: *Adenolobus pechuelii – Commiphora saxicola* community

This community is found most prominently on the gravelly slopes and small washes of eroded conglomerate deposits northeast of the mine. *Commiphora saxicola* and *Zygophyllum stapffii* are relatively common, albeit in low densities. The low shrub *Adenolobus pechuelii* (Namib neat's-foot), with its conspicuous yellow flowers and red pods is indicative of this community. A high number of seedlings of this shrub show that it should be possible to regenerate fair stands of this species from seeds. The sub-shrub *Monechma cleomoides* as well as the larger *Calicorema capitata* are further characteristic features, although more concentrated along drainage lines. The remainder of the species is mostly annual species, of which the grass *S. hirtigluma* subsp *hirtigluma* may become dominant during favourable seasons.

Species diversity is moderate, but may be very patchy and vary extremely during years. This community has been given a sensitivity rating 2, where slower-growing perennial vegetation can be relocated to other locations and even other habitats where necessary.

9: The *Zygophyllum stapffii – Sesamum marlothii* association

This association is not further divided and thus listed as community 9. These dense riverine shrublands prefer the narrow runoff channels between schist outcrops flowing into the Gawib River from the Schieferberg (habitat F), as well as from small schist outcrops northeast of the mine.
2004 EIA: This community has been incorporated into the *Calicorema capitata – Monechma cleomoides* washes and *Calicorema capitata – Zygophyllum stapffii* rocky river terraces.
Both the shrubs *Calicorema capitata* and *Zygophyllum stapffii* form the dominant part of this vegetation, often reaching a high density and surface cover. *Stipagrostis hirtigluma* subsp *hirtigluma* may be equally common during favourable seasons. Common sub-shrubs are *Anticharis imbricata, Petalidium canescens* and *Tephrosia dregeana*. Common herbs include *Euphorbia phylloclada, Sesamum marlothii* (with its large pink flowers) and *Zygophyllum simplex*.
Species diversity is moderate, yet patchy and variable between seasons. The finer-grained soils do not offer a very favourable moisture regime, yet this community may receive a high amount of runoff from surrounding slopes. Also, this narrow riverine environment often extends far south of the mining lease area, and are thus an important resource link and channel through the larger ecosystem. Testimony to this are the frequent fresh tracks of mammals found in these channels. The sensitivity rating of 3 indicates that development in these areas should be avoided as far as possible. The channels may not be blocked off, and natural flow of resources to the Gawib River itself should be restored after mine closure.

The *Trianthema triquetra – Stipagrostis hirtigluma* association is subdivided into communities 10, 11 and 12, occurring on the rocky surfaces of the schist outcrops and the conglomerate terraces. Perennial shrubs are concentrated towards steeper slopes or runoff channels, while the remainder of the ridges are covered with sparse grasslands, and may be relatively bare during the dry season.
2004 EIA: These communities had been incorporated into the *Salsola tuberculata* limestone outcrops and flats and *Petalidium setosum* schist outcrops and hills.

10: *Enneapogon desvauxii – Euphorbia phylloclada* community

This community is found on the upper and usually flatter schist ridges of the northern parts of the Schieferberg (habitat G), thus south of the mine. Solitary stem succulents *Hoodia currorii* (Namib Hoodia) and *Euphorbia virosa* (large milk bush) can be found, whilst occasional shrubs of *Euphorbia guerichiana* and *Commiphora saxicola* are also present. However, most of the vegetation is made up of short-lived ephemerals, of which *Stipagrostis hirtigluma subsp hirtigluma* often forms the dominant layer, with patches of *S. ciliata*. The succulent herb *Trianthema triquetra* are a common feature on these ridges, as are *Euphorbia phylloclada* and *Pegolettia senegalensis*.
Within the context of this study, the species diversity of this community is low, affording it a sensitivity rating of 1. However, not all of this community is expendable, as it is situated on an important runoff area, on which community 11 depends.

11: *Petalidium canescens – Commiphora saxicola* community

The presence of this community on the Schieferberg (habitat G) is dictated to a very large extend by topographical features such as steeper slopes, aspect of slope as well as runoff channels. The densest patches of this community are found in the upper edges of the runoff channels, where more water collects. The most conspicuous species here is the shrub *Commiphora saxicola*, of which numerous young individuals have been observed, as well as specimens with a considerable amount of fruit. Another common shrub is *Cryptolepis decidua*. The *sub-shrub*s *Anticharis imbricata*, *Petalidium cansecens, Psilocaulon salicornioides* and *Tephrosia dregeana* are common, occasionally in higher densities. *Stipagrostis* species often form the dominant layer of the vegetation, but during dry seasons only patches of *Stipagrostis uniplumis* and *S. ciliata* may remain.

Species diversity is moderate but highly patchy, yet should be awarded a sensitivity rating of 2. Together with community 10, the best new sacrificial area for mine dumps will be between the water reservoirs and the current telephone line. Several perennial shrubs and succulents that occur here as part of these communities can be relocated.

Warning: Should large, much-branched specimens of *Euphorbia virosa* occur on a selected sacrificial area, it is advised NOT to remove these specimens. Sacrificing these specimens will not endanger the survival of the species in any way, however, *Euphorbia virosa* is known as the most poisonous of the Euphorbia's. Its milky latex is severely caustic and may cause severe wounds and flows readily as the plant is injured; people have already died after using the wood of such dead plants for a barbeque. Attempts can be made to try and relocate the shrubby *Euphorbia guerichiana* and *Commiphora* species, whilst *Hoodia* species should be easy to relocate.

12: *Eragrostis nindensis – Trianthema triquetra* community

This community is most prominent on top of the conglomerates of the old valley fill deposits overlying various outcrops north and northeast of the current mining area (habitat H). These relatively level areas are rather exposed and have only few patches where water does accumulate, providing a relatively harsh environment. This is reflected in the very sparse shrubby vegetation present, mostly of the species *Salsola tuberculata* and *Calicorema capitata,* whilst *Commiphora* species occur along the upper edges of runoff channels. *Stipagrostis* species form the dominant plant layer, but these may disappear during unfavourable seasons. An important species remaining is *Eragrostis nindensis*, a very low, but hardy perennial grass, that is also capable of trapping and stabilising soil due to its dense basal tuft. According to Nel (1983), it can complete its entire annual growth cycle with only 20 mm of rain. Although it does not have a very high production, in the Namib it is readily consumed by animals, which is partly attributable to the fact that this is often the only grass species present, and also one of the first species to resprout after rains. Further species indicative on these plains are *Trianthema triquetra, Enneapogon desvauxii* and *Zygophyllum simplex*.

Species diversity is moderate, and based on that, the area has a sensitivity rating of 2. However, some of these plains are situated above very sensitive quartzite slopes (northwest of the mine), or form large continuous 'plateaus' (directly north of the mine), where they are occasionally frequented by animals, and these patches therefore have a sensitivity rating of 3. The more eroded areas between the current tailings dam and the explosive store may be regarded as a sensitivity 2 zone.

Fodder plants

The following information has been extracted from Nel (1983).

Most important fodder grasses:

Antephora pubescens: occurs only on the quartzite slopes, where it is often difficult to reach. As tufts do not form dense stands, this otherwise palatable grass is not utilised during favourable seasons. However, during periods of drought, it is very well utilised, as it then also has a high amount of dry standing biomass.

Enneapogon desvauxii: prefers shallow soils, and is very common on calcretes. Although very low and often sparse, it is one of the grasses well utilised by mountain zebra.

Eragrostis nindensis: it can complete its entire annual growth cycle with only 20 mm of rain. Although it does not have a very high production, in the Namib it is readily consumed by animals, which is partly attributable to the fact that this is often the only grass species present, and also one of the first species to resprout after rains. It is associated with shallow soils on level plateaus, as well as deeper soils on drainage lines. In the study area it is most prevalent on the northern gravelly and conglomerate plateaus.

Stipagrostis ciliata: this is regarded as the most important grazing component of the Central Namib. It prefers loose, coarse and sandy soils, but may also occur on calcretes. Once established, it can withstand longer periods of drought, but may behave as an annual. It is found throughout the study area.

Stipagrostis hirtigluma: can be found on a wide range of soils throughout the study area, but is most prevalent on otherwise relatively bare ridges and plateaus. It is annual, but can germinate after only 15 mm, and grows fast to provide a temporary source of fodder. However, copious amounts of seeds produced also provide food for various smaller forms of fauna.

Stipagrostis obtusa: this grass is often found in association with *S. ciliata*, but prefers the lower plains and footslopes, where it may become dominant. Although the leaves are rolled up in a tight basal tuft, in the dormant state it is softer than *S. ciliata* and then also the more palatable species during dry periods.

Stipagrostis uniplumis: it prefers more stable soils, either in the upper edges of runoff channels, or on deeper sandy soils. In the study area it usually grows on the schist ridges and runoff channels, but never forms significant stands. This grass is only palatable when actively growing, when the culms are relatively soft.

Low shrubs utilised by game:

Small shrubs and forbs are an important source of fodder for larger herbivores. Species that are utilised the most are:

Adenolobus pechuelii, Zygophyllum cylindrifolium and *Salsola* species. *Calicorema capitata, Monechma cleomoides* and *Petalidium variabile* have been shown to deliver a very high proportion of the diet of local herbivores (Nel 1983). These three species will also form the bulk of herbivore diet during prolonged periods of drought. They are most common in all riverine systems throughout the study area, as well as on the quartzite slopes.

Herbs that are well utilized by game:
These include:
Indigofera auricoma, Cleome species, Zygophyllum simplex, Tribulus zeyheri (during early stages of growth), *Citrullus ecirrhosus*, *Cucumis* species and *Sesamum* species, especially *Sesamum marlothii* (Pers. Obs.).

Trees that are utilised by game:
Acacia erioloba is regarded as the most important fodder- and shade tree in the Central Namib. Its pods are available during the hottest period of the year, before the onset of rains. Further, it not only traps but also produces a large amount of debris, which acts as a source of humus to the surrounding soil, and traps seeds of various plants that then germinate there.

Boscia foetida is the shrub that endures the most vigorous utilisation within the Central Namib. Apart from its leaves and softer stem tips, the fruit, often produced in abundance, are another important source of food to fauna.

Euclea pseudebenus is another tree valued by game for its shade, leaves and berries, which are even eaten by black-backed jackal. Similar to *Acacia erioloba*, a significant amount of humus accumulates below its canopy, providing a favourable habitat for other species.

Commiphora leaves are relatively well utilised by springbuck and rock hyrax, where these animals can reach them, whilst the bark is popular with porcupines.

Ficus cordata fruit are well utilised by rosy-faced lovebirds and baboons, whilst baboons and porcupines also feed on the bark of this tree.

Maerua schinzii has been shown to be well utilised by oryx and kudu (Nel 1983; Pers. Obs.).

General Recommendations
Monitoring programs
There exists very little information on the establishment and growth-rate of seedlings of shrubs and trees in the Namib. Some information can, however, be collected now in the part of the mine, that will be most severely disturbed – i.e. the riverbed. Areas not envisaged to be excavated should be surveyed as soon as possible for the presence of seedlings, with priority given to *Acacia erioloba*. The methodology is relatively rapid, and surveys only need to be repeated every 3 or 4 months: a rectangular area with a fair amount of seedlings is selected, preferably of several species. The area should not be wider than 1m, but can be up to 10m long. The central line along that area is marked with permanently positioned pegs, between which a measuring tape can be stretched during every survey. During the initial survey, every seedling is assigned a number and its position recorded on a graph paper, where the monitor-

ing site can be drawn in according to scale. For every seedling, the approximate height (e.g. height classes of about 25 cm intervals) is recorded during every survey, as well as its vigour: growing well if full of leaves, dormant during the dry season or dead.

Such data will be very useful to determine growth rate and survival of various seedlings. This data will help to create realistic expectations for restoration plans after the mine completes operation in a particular area. The data may also give insights as to where and how much natural processes may have to be ‘assisted’, e.g. by occasional watering or the necessity to raise plants in a nursery.

Monitoring of establishment of transplanted plants

Although several plants have already been transplanted, feedback on the success of establishment varied probably indicating limited translocation success. In future, it would be advisable if a representative sample of transplanted plants, especially where protected species are concerned (including stem succulents), are actually planted along a linear transect (e.g. within 1 m of a demarcated line) to enable the same monitoring procedure as for seedlings. However, this will still necessitate such plants to be placed in similar habitats, and not planting them in a straight line.

Again, data collected here will not only show how well which species can be transplanted and help to create realistic restoration goals, but will also highlight potential problems that may have to be addressed to ensure the continued survival of these plants.

Topsoil storage

It may not be feasible to store topsoil of all areas mined. Priority should however go to the sandy soils from the Gawib River itself. These are an accumulation over hundreds of years of weathered material from the surrounding mountains, and there is no additional source of these soils. The vegetation on these alluvial deposits depends on this portion of their habitat able to be re-establish. It will also be desirable not to dump such topsoil in small heaps, but rather to flatten it out to create an interim surface, on which seeds can germinate and such plants help to strengthen the seed bank in these soils.

Acquisition of suitable remote sensing material to facilitate future studies

The Remote Sensing Unit of the CSIR in Pretoria is currently investigating and acquiring several formats of satellite imagery, from which mapping of sparse desert vegetation may be done more accurately. Such satellite imagery may further be useful to produce a 3D image of the terrain, as well as assist in groundwater studies. More accurate vegetation mapping for the remainder of the mining licence area will depend on the type and quality of such remote-sensing data. From high resolution aerial photographs the distribution of larger trees and shrubs may be deducted, but such photos give no information as to the delineation of other vegetation or communities. For this actual reflectance data is necessary, which measures the types and intensities of chlorophyll, heat reflectance as well as turgor (water content) of plants, which is characteristic for different types of vegetation. It is recommended that CSIR specialists be contacted for the best satellite imagery to be attempted.

Recording rooting depth

Poor data exists on the depth of roots of the riverine vegetation, which will become an important issue when tailings or waste rock are filled into pit areas. One opportunity to solve this would be to try and do root counts where a pit wall is extended into still existing vegetation. For this, a rectangular area of about 50 cm is marked onto a freshly cut pit wall, and extended from top to bottom. For every 50 x 50 cm square, the number of roots can be counted without too much effort. Ideally roots should be divided into woody and non-woody roots, as this is an indication of their parent plant – trees and larger shrubs or smaller shrubs, forbs and grasses.

Obtaining soil data

Currently there are no data available on the soil characteristics of the areas where different plant communities occur. Data that is needed includes soil conductivity, acidity, texture and nutrient status. Materials excavated from the pit area will most likely have very different characteristics than current topsoils. To enable proper planning and realistic expectation for restoration practices after mine closure, the difference between existing topsoils and soils that may later be used as topsoils needs to be known.

Planning with the environment

Allow sufficient time for identifying and excavating plants that need to be removed. The environmental section must be involved and fully informed of all plans for new dumping sites right from the start. The environmental section will need sufficient time to survey the area to make sure they remove and transplant all suitable plant specimens. The National Botanical Research Institute will also welcome some of these specimens for the Botanical Garden.

Discussion and Conclusion

The Gawib River is one of the larger and more diverse river systems within the Central Namib. The section of the Gawib River that bisects the Langer Heinrich Mountains and the Schieferberg is potentially the most diverse and unique habitat within this river system, due to the enhanced runoff from the adjacent mountains. This is reflected in the relatively high species diversity compared to the surrounding areas of the Central Namib. On a larger scale, this section of the Gawib River is an important link and passage from higher lying plains on the east, up to the Tinkas watershed, and the plains and larger river systems to the west and north. The Langer Heinrich Mine is situated exactly in the centre of this link, potentially blocking off resource flows. This has already become evident during a rare but significant rainfall event early in 2008.

Approximately 25% of the species recorded are endemic; some of these, like *Aloe namibensis*, have a very narrow distribution, and parts of the study area provide an ideal habitat for these plants. The latter statement is supported by observations on the size-distribution of some of the plant species. For all *Commiphora* species, *Aloe namibensis, Euphorbia guerichiana, E. virosa*, which have their prime habitat in the Central Namib, size-classes of individuals ranged from recent seedlings, to juveniles (established plants but too young to flower), to very large plants. This shows that these species are reproducing well and the populations are currently stable. For the larger trees – i.e. *Acacia erioloba*, *Boscia* species, *Euclea pseudebenus*, *Ficus cordata, Maerua schinzii, Parkinsonia africana* and *Sterculia africana* the only seedlings found were for *Acacia erioloba*. Juvenile plants were even scarcer, and only included specimens of *Acacia erioloba* and *Parkinsonia africana*. This phenomenon is probably due to two factors: either the plants become very old and can persist readily in an undisturbed habitat, thus the necessity of large seed-production is small (as is the case with *Welwitschia mirabilis*), or these species are only able to become established during successive years of sufficient rainfall, and take very long to reach their present size because of the harsh environment. As these species are also restricted to specific habitats, the second scenario is more likely. This, of course, has major implications for the impact of the mine. Whilst *Sterculia*, *Ficus* and some *Boscia* species occur on habitats where no ore has yet been identified and can be protected from disturbance, the same does not apply to the Gawib channel itself. It is envisaged that the majority of the large specimens of *Acacia erioloba, Euclea pseudebenus* and *Maerua schinzii* will disappear as mining activities progress. As these trees provide important habitat to other plant species as well as fauna, whilst also contributing to the overall functioning of the ecosystem, planning of mine activities will have to consider mitigating activities in these areas (shown in Figure 5) from the start.

Figure 5: *Areas where mitigation measures will become necessary are indicated in green. Of these, possible key seeding areas, indicated in blue, should be treated as NO GO areas. The approximate position of current stock piles, tailings facility, and mine dumps are indicated in brown.*

The following will be necessary:

- Identify key patches of preferably denser stands of these trees that fall outside the ore body, and demarcate them as seeding areas for future regeneration purposes. Disturbance of these key areas (possible sites indicated in Figure 5) must be prevented.
- Store topsoil from the sites that will be excavated in future.
- Monitor seedling establishment and growth in seeding areas, and establish nurseries if seedlings succumb early.

Within the current core area of the Langer Heinrich Mining Lease, there are areas where, due to harsh environmental conditions, plant species diversity is relatively low. These areas are mostly to the south of the mine, on the lower schist outcrops of the Schieferberg, as well as adjacent low footslopes. Other areas with low plant biodiversity are the relatively instable conglomerates, north and north-east of the current mine. In all of these areas, perennial shrubs, dominated by *Commiphora saxicola* and *C. virgata*, are concentrated along runoff channels or steeper slopes that are partly shaded. Despite the lower plant species diversity here, most of the lower parts of the tributaries coming from the Schieferberg are frequented by larger mammals. The same applies to the conglomerates, which, despite their low vegetation cover, support grazing that will be available during times of very poor precipitation, when no other grasses may have foliage. This means that even low plant diversity areas also need to be protected to some degree.

On the conglomerates and the Schieferberg, four areas have been identified where mining activities are expected to have minimal impact on the vegetation. Of these, the schist outcrops between the current water reservoirs and telephone line, as well as the gravelly footslopes and plains north-west of these outcrops, appear to be the most suitable for permanent dumping sites, provided that no undesirable material can be re-distributed into lower-lying tributaries (See sites 1 and 2 – Figure 6). However, many remnants of bulbous plants were found on the gravelly footslopes and plains (site 2), which could not be identified. Collecting bulb specimens for identification is thus imperative. Furthermore, as bulbous plants are in general poorly known in Namibia, but may be an important food source for some animals, topsoil will have to be removed and bulbs salvaged. These bulbs can easily be kept in a nursery, and transplanted again at a later stage.

The low foothills south-east of the new low grade ore stockpile could be used to extend the stockpile (See site 3 – Figure 6). However, care should be taken not to block off the tributaries from the Schieferberg, whilst also minimising the disturbance of the Gawib channel itself.

A smaller site that may be suitable for storing topsoils, are the relatively eroded conglomerate ridges and blind valleys west of the current explosives store and the north-east of current tailings dam (See site 4 – Figure 6, area indicated in Figure 7).

Waste Rock Dump 1 should be filled up right to the end of the blind valley against the conglomerates. Waste Rock Dump 2 already infringes on very sensitive habitat on the western channel it uses, and should rather be extended to the east.

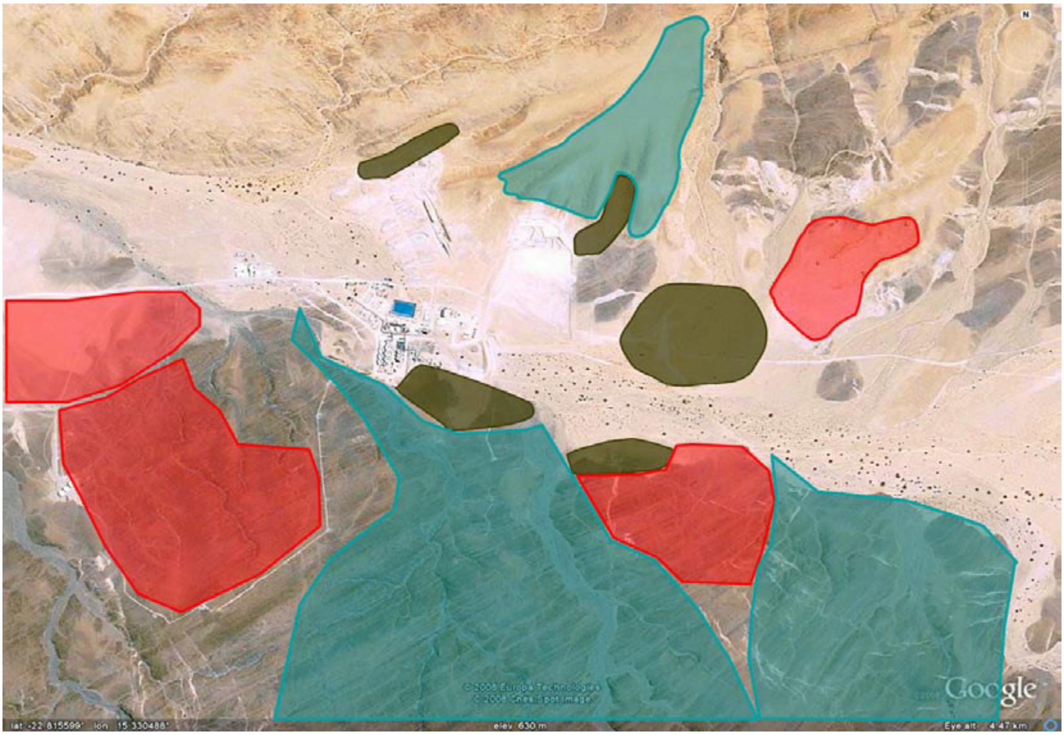


Figure 6: *Possible sacrificial areas are indicated in red. Areas with lower sensitivity that should be retained due to more niche availability and animal presence are indicated in green. The approximate position of current stock piles, tailings facility, and mine dumps are indicated in brown.*

Figure 7: *Two blind conglomerate valleys northeast of the current tailings dam that could be used to store topsoil.*

The quartzite slopes, ravines and boulder washes spanning the northern portion of the mining lease support the highest diversity of plants within the core mining area with 92% of all plants that could be identified during the survey represented here. As this area lies outside the ore body, there is no justification for any disturbance of these areas (Figure 8).

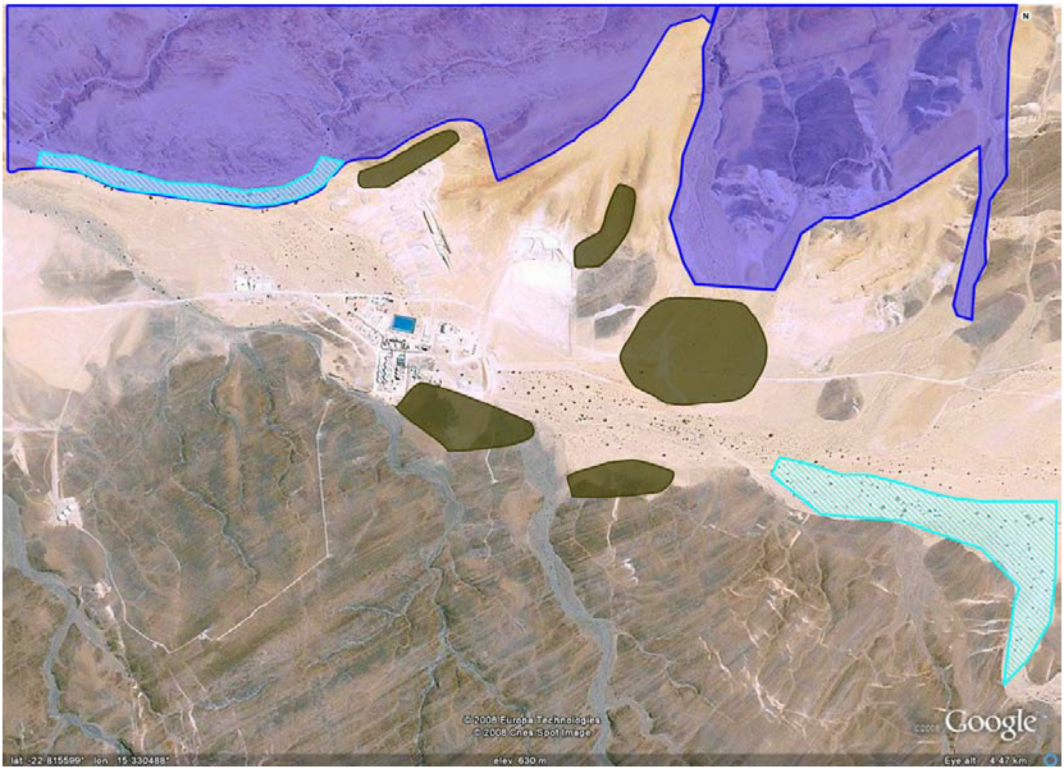


Figure 8: *NO GO areas with high biodiversity and niche availability are indicated in dark blue. Also indicated are the possible key seeding areas, representative of the Gawib River vegetation that should be treated as NO GO areas as well. The approximate position of current stock piles, tailings facility, and mine dumps are indicated in brown.*

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Appendix 1 - Overview of the plant associations and communities:

1. The *Commiphora glaucescens – Aloe namibensis* association

Communities:	Habitat	Most important species
1.1 Commiphora virgata – Zygophyllum cylindrifolium sparse shrublands Community statistics: 2 restricted endemics 10 narrow endemics 11 widespread endemics 1 Red Data species 4 protected species 4 keystone species 93 observed species 115 expected species Sensitivity score: 538 **Irreplaceable community and habitat**	Found on quartzite slopes, outcrops and upper runoff channels. These are part of the larger Langer Heinrich Mountain, thus relatively limited within the study area and it is expected that the habitat may be limited beyond the study area as well **Management implications:** This community and habitat should be disturbed as little as possible. The relatively high incidence of the red-listed *Aloe namibensis*, as well as the high number of observed and expected species indicates that this area should, as far as possible, be treated as a non-disturbable conservation area.	**Constant species:** *Antephora pubsecens (Wool grass), Aristida parvula,* *Commiphora glaucescens (Blue-leaved Commiphora),* *Commiphora virgata (Slender corkwood)* *Enneapogon desvauxii* *(Eragrostis nindensis (Eight-day love grass)* *Hermannia helianthemum* *Indigofera auricoma* *Monechma cleomoides (Namib perdebos)* *Pegolettia senegalensis* *Petalidium variabile (variable Petalidium)* *Stipagrostis ciliata (tall bushman grass)* *Stipagrostis hirtigluma* *Stipagrostis uniplumis* *Tephrosia monophylla (single-leaf Tephrosia)* *Zygophyllum cylindrifolium* *Zygophyllum stapfii (dollarbush)* **Unique species:** *Aloe namibensis (Namib aloe)* *Boscia foetida (Noeniebos)* *Euphorbia guerichiana (Paper-bark Euphorbia)* *Euphorbia virosa (Candelabra Euphorbia)* *Helichrysum tomentosulum* *Sesamum marlothii* *Sterculia africana (Ticke tree)*

1.2 Petalidium variabile – Aloe dichotoma sparse shrublands

Community statistics:
5 restricted endemics
16 narrow endemics
18 widespread endemics
2 Red Data species
9 protected species

7 keystone species
138 observed species
164 expected species

Sensitivity score:
786

Irreplaceable community and habitat

Granitic boulders, flats and outcrops as found in localised areas in the eastern portion of ML140, where the overlying schists have eroded away. The granites closest to the present mine are just south of the prospectors camp. This habitat does occur extensively around the study area, especially towards the Swakop River and Tinkas Mountains. However, due to their position within the study site and its landscapes, these granites are expected to be significantly different in species composition compared to granites found elsewhere in the country, e.g. Erongo.

Management implications:

This community and habitat should be disturbed as little as possible, it will be impossible to reacreate it. The high number and diversity of niches available are responsible for the high plant diversity found here.

Constant species:

Asparagus pearsonii
Calicorema capitata
Calostephane divaricata
Chamaesyce glanduligera
Commiphora glaucescens
Commiphora virgata
Enneapogon desvauxii
Enneapogon scoparius
Eragrostis nindensis
Hermannia helianthemum
Indigofera auricoma
Monechma cleomoides
Petalidium variabile
Stipagrostis ciliata
Stipagrostis hirtigluma
Stipagrostis uniplumis
Tephrosia dregeana
Tephrosia monophylla
Zygophyllum stapffii

Unique species:

Aloe dichotoma (Quiver tree)
Aloe namibensis (Namib aloe)
Amphiasma divaricatum
Aptosimum angustifolium
Boscia albitrunca (Witgat)
Engleria africana
Euphorbia virosa (Candelabra Euphorbia
Grewia tenax
Hoodia currorii
Jamesbrittenia hereroensis
Maerua schinzii

1.3 Sterculia africana – Enneapogon sparse shrublands

Community statistics:
2 restricted endemics
9 narrow endemics
10 widespread endemics
1 Red Data species
3 protected species

2 keystone species
73 observed species
91 expected species

Sensitivity score:
500

Irreplaceable community and habitat

Quartzite ravines

Constant species:

Abutilon pycnodon
Anthephora pubescens
Anticharis imbricata
Barleria merxmuelleri
Commiphora glaucescens
Cucumella aspera
Dyerophytum africanum
Enneapogon scaber
Enneapogon scoparius
Forsskaolea candida
Hermannia helianthemum
Monechma cleomoides
Ruellia diversifolia
Stipagrostis hirtiglum
Trichodesma africanum

Unique species:
Barleria merxmuelleri
Ficus cordata
Forsskaolea candida
Helichrysum tomentosulum
Marcelliopsis splendens

1.4 Petalidium variabile – Stipagrostis hochstetteriana sparse shrublands Community statistics: 4 restricted endemics 16 narrow endemics 14 widespread endemics 1 Red Data species 3 protected species 6 keystone species 118 observed species 138 expected species Sensitivity score: 656 **Irreplaceable community and habitat**	Quartzite boulder washes	**Constant species:** Adenolobus pechuelii Barleria lanceolata Blepharis grossa Calicorema capitata Chamaesyce glanduligera Cleome foliosa Forsskaolea candida Geigeria alata Hermannia helianthemum Indigofera auricoma Kohautia ramosissima Monechma cleomoides Petalidium variabile Sesamum marlothii Stipagrostis ciliata Stipagrostis hochstetteriana Stipagrostis uniplumis Tephrosia monophylla Trichodesma africanum Tripteris microcarpa **Unique species:** Boscia foetida Euphorbia guerichiana Fagonia sinaica v. minutistipula Heliotropium hereroense Jamesbrittenia hereroensis Polygala guerichiana Sesamum marlothii Sterculia africana Stipagrostis damarensis Stipagrostis schaeferi

2. *Trianthema triquetra – Stipagrostis hirtigluma* association

Communities:	Habitat	Most important species
2.1 Eragrostis nindensis – Trianthema triquetra sparse grasslands Community statistics: 1 restricted endemics 7 narrow endemics 3 widespread endemics 0 Red Data species 1protected species 2 keystone species 50 observed species 63 expected species Sensitivity score: 242 **Sensitive community and habitat**	Conglomerate flats and upper slopes **Management implications:**	**Constant species:** **Unique species:**
2.2 Adenolobus pechuelii – Zygophyllum cylindrifolium sparse grasslands Community statistics: 3 restricted endemics 11 narrow endemics 9 widespread endemics 1 Red Data species 3 protected species 4 keystone species 83 observed species 108 expected species Sensitivity score: 450 **Irreplaceable community and habitat**	Pegmatite intrusions on schist ridges **Management implications:**	**Constant species:** **Unique species:**

2.3 Enneapogon desvauxii – Pegolettia senegalensis sparse grasslands Community statistics: 1 restricted endemics 6 narrow endemics 3 widespread endemics 0 Red Data species 3 protected species 2 keystone species 55 observed species 71 expected species Sensitivity score: 200 **Least sensitive community and habitat**	Schist ridges	**Constant species:** **Unique species:**
2.4 Petalidium canescens – Commiphora saxicola sparse grasslands Community statistics: 0 restricted endemics 8 narrow endemics 2 widespread endemics 0 Red Data species 0 protected species 2 keystone species 52 observed species 69 expected species Sensitivity score: 224 **Sensitive community and habitat**	Steeper schist slopes and runoff channels	**Constant species:** **Unique species:**

3. *Zygophyllum stapffii – Sesamum marlothii* association

Communities:	Habitat	Most important species
3.1 Zygophyllum stapffii – Sesamum marlothii riverine shrublands Community statistics: 1 restricted endemics 6 narrow endemics 4 widespread endemics 0 Red Data species 1 protected species 3 keystone species 56 observed species 78 expected species Sensitivity score: 322 **Highly sensitive community and habitat**	Narrow flood channels between schist outcrops and mountains, with schist gravel and / or boulders **Management implications:**	**Constant species:** **Unique species:**

4. *Calicorema capitata – Stipagrostis schaeferi* association

Communities:	Habitat	Most important species
4.1 Acacia erioloba – Stipagrostis damarensis sparse shrublands with low trees Community statistics: 2 restricted endemics 16 narrow endemics 14 widespread endemics 0 Red Data species 5 protected species 7 keystone species 127 observed species 148 expected species Sensitivity score: 662 **Irreplaceable community and habitat**	Sandy washes and rivers	**Constant species:** **Unique species:**

4.2 Acacia erioloba – Stipagrostis ciliata sparse shrublands with low trees Community statistics: 2 restricted endemics 9 narrow endemics 9 widespread endemics 0 Red Data species 4 protected species 7 keystone species 87 observed species 110 expected species Sensitivity score: 432 **Highly sensitive community and habitat**	Sandy or gravelly river terraces	**Constant species:** **Unique species:**
4.3 Adenolobus pechuelii – Stipagrostis ciliata sparse shrublands with low trees Community statistics: 3 restricted endemics 10 narrow endemics 11 widespread endemics 0 Red Data species 2 protected species 4 keystone species 96 observed species 115 expected species Sensitivity score: 400 **Highly sensitive community and habitat**	Small shallow washes	**Constant species:** **Unique species:**

5. *Stipagrostis obtusa – Zygophyllum simplex* association

Communities:	Habitat	Most important species
5.1 Aizoanthemum rehmannii – Monechma desertorum sparse grasslands Community statistics: 1 restricted endemics 6 narrow endemics 4 widespread endemics 0 Red Data species 0 protected species 1 keystone species 59 observed species 76 expected species Sensitivity score: 138 **Least sensitive community and habitat**	Schist and calcrete plains and footslopes	**Constant species:** **Unique species:**
5.2 Salsola tuberculata – Jamesbrittenia barbata sparse grasslands Community statistics: 2 restricted endemics 7 narrow endemics 2 widespread endemics 0 Red Data species 0 protected species 1 keystone species 40 observed species 46 expected species Sensitivity score: 160 **Least sensitive community and habitat**	Quartz gravel plains and erosion slopes	**Constant species:** **Unique species:**