DETERMINING THE PRESENCE OF VACHELLIA ERIOLOBA TREES AND THE EFFECT GROUND WATER ABSTRACTION FOR MINING RELATED ACTIVITIES WILL HAVE ON V. ERIOLOBA AQUIFER (GROUND WATER) DEPENDANT ECOSYSTEMS, WITHIN THE NORTHERN CAPE PROVINCE

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ACRONYMS

ADE/GDE	Aquifer (Groundwater) Dependant Ecosystems
DMR	Department of Mineral Resources
DWAF	Department of Water Affairs and Forestry
DWS	Department of Water Affairs and Sanitation
EIA	Environmental Impact Assessment
NFA	National Forest Act
NWA	National Water Act (Act 36 of 1998)
RDM	Resource Directed Measures
STS	Scientific Terrestrial Services
XPP	Xylem Pressure Potential

1 INTRODUCTION

1.1 Background

Scientific Terrestrial Services (STS) was appointed to conduct an investigation into the dependency of *Vachellia erioloba* trees on ground water resources, as well as the effect of ground water extraction for the proposed Khwara mine, near Hotazel, upon *V. erioloba* populations situated within the area affected by the ground water abstraction point. The farm portions, on which the cone of depression as a result of the abstraction process will form, will hence forth be referred to as the "study area".

The R380 traverses the central portion of the study area, with the R31 situated approximately 7.4 km to the south. The town of Hotazel is located approximately 14.4 km southeast of the study area, while Kathu is located approximately 68km to the south, and Kuruman 65 km southeast. The study area is further located within the John Taolo Gaetsewe District Municipality. Figures 1 and 2 below indicate the study area, cone of depression, as well as an approximate location of the proposed shaft.

Khwara Manganese (Pty) Ltd (Khwara) holds a prospecting right for manganese on portion 2 of the farm Wessels 227 and the remaining extent and portion 3 and 4 of the farm Dibiaghomo 226, north of Black Rock in the Northern Cape Province. Khwara has applied for a mining right over these portions of the farms Wessels 227 and Dibiaghomo 226. The underground manganese resource will be accessed and mined from the neighbouring approved Lehating Mine.

Mining will be conducted using the trackless mechanised bord and pillar mining technique. This technique is typical in the Kalahari Manganese Field and is used in all wide body mines from the perspectives of safety and productivity. It is anticipated that 0.55 million tonnes per annum of ore will be mined as part of the proposed project. The ore body is located at a depth of 220 m to 350 m meters below surface with a thickness of approximately 5 m to 9 m. Khwara will conduct dewatering to ensure a safe working environment and this water will be reused for dust suppression and in the Lehating process water circuit.

Minimum waste rock is expected to be generated by the proposed project as mining will be carried out on reef via Lehating's underground mine. In the event that waste rock is generated, waste rock will either be loaded into a rear tipper truck and then transported to the waste rock stockpile at the Lehating Mine, or stored underground. The approved Lehating Mine will be able to support any waste rock generated by the proposed project for the short to medium term. Therefore no additional waste rock capacity is required for the proposed project.

Approved surface infrastructure at the Lehating Mine will be used to support the mining of the Khwara manganese resource, therefore no surface infrastructure will be established as part of the proposed Khwara Project. Given that the project will not add processing capacity to the Lehating Mine, the already approved surface infrastructure on Lehating Mine will be adequate to support and process the ore generated by mining of the Khwara manganese resource. Therefore no additional facilities, or increase in capacities of facilities or services will be required in the short to medium term.

Underground mining activities will take place 24 hours a day, seven days a week. These operating times will coincide with the Lehating Mine operating times.

The Lehating Mining Project is planned to commence in 2018. The Khwara ore body will be accessible through Lehating's underground development in 2036. Therefore, subject to DMR approval, Khwara underground mining will commence in 2036 for a period of approximately 10 years.

Decommissioning and closure activities associated with the proposed project will form part of the overall Lehating Mine decommissioning and closure related activities. Decommissioning related activities specific to the proposed project however will include providing underground support and post closure monitoring.

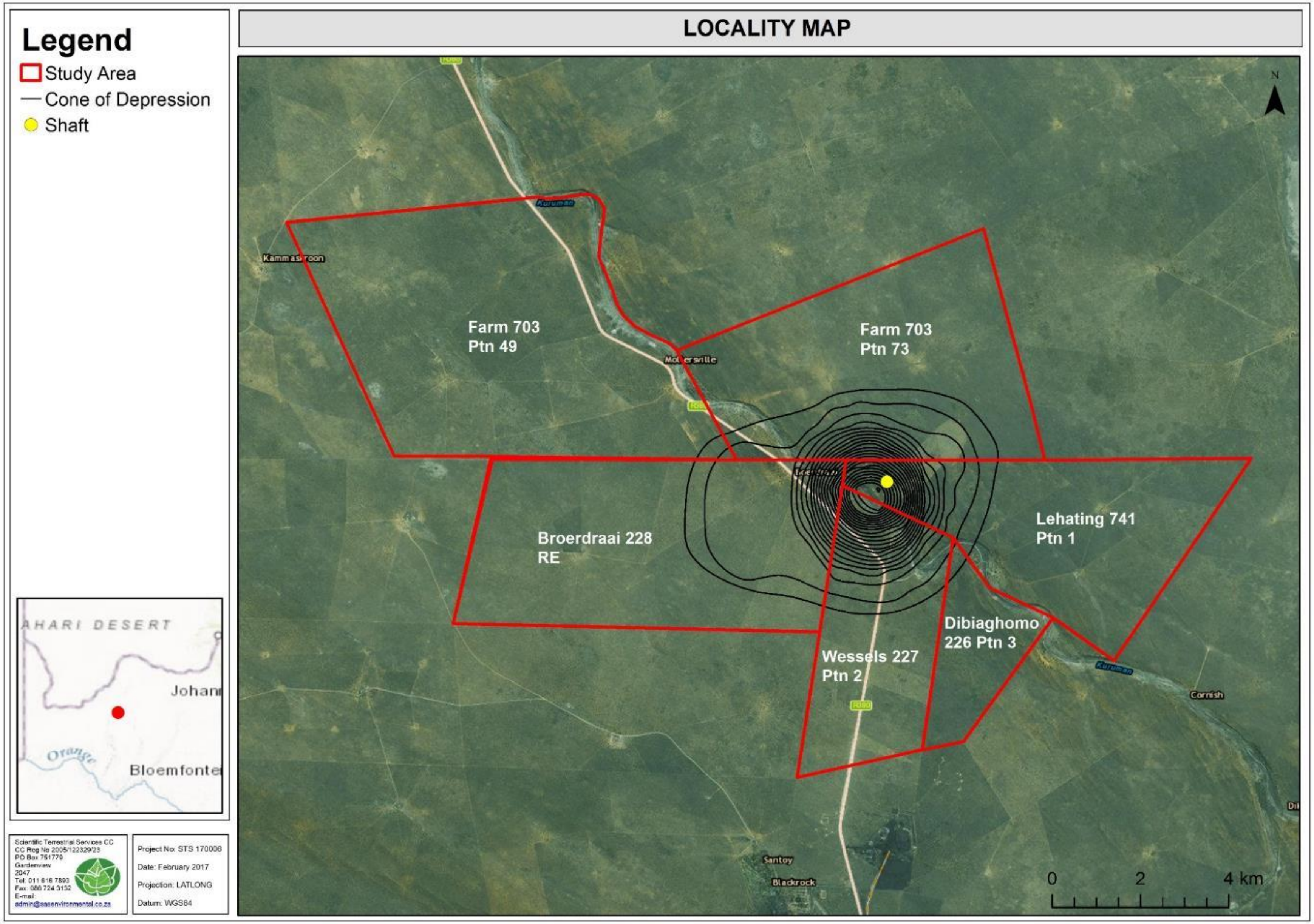

Figure 1: Digital satellite image depicting the location of the study area in relation to surrounding areas.

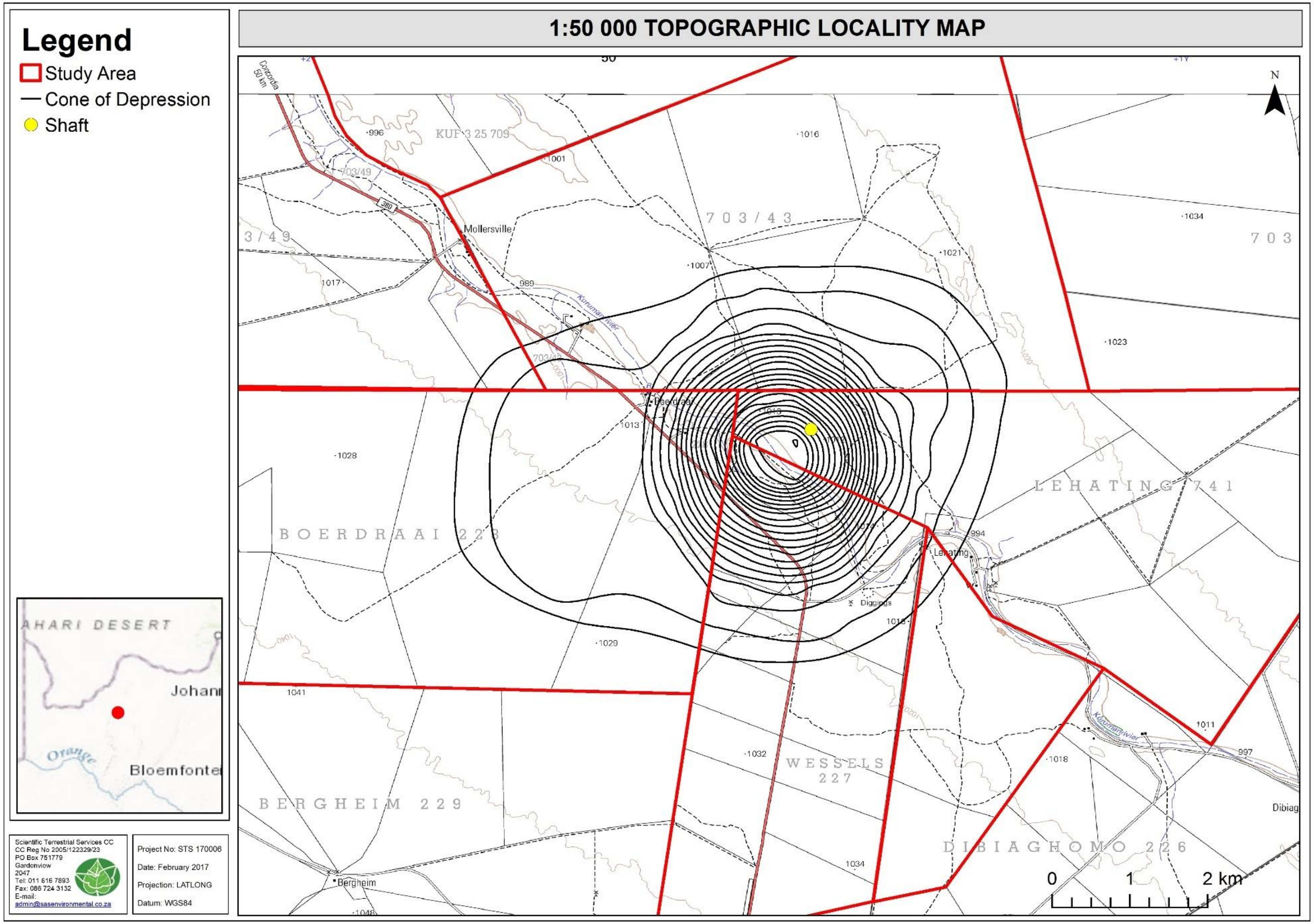

Figure 2: Location of the cone of depression depicted on a 1:50 000 topographical map in relation to surrounding areas.

1.2 Project Scope

Specific outcomes in terms of the ecological assessment are as follows

- To conduct a literature review regarding aquifer (ground water) dependant ecosystems (ADE/GDE), and the dependency of *Vachellia erioloba* on ground water in particular. This study further includes case studies on the effect of ground water abstraction on ADEs;
- A field assessment identifying the presence of *V. erioloba* populations situated within cone of depression area;
- Identifying which populations within the study area might be more severely affected by the lowering of the water table, which will require future, ongoing monitoring for signs of water deficiency; and
- Provide management and monitoring objectives and protocols to mitigate any anticipated impacts on ADE.

1.3 Assumptions and Limitations

The following assumptions and limitations are applicable to this assessment:

- The exact depth of the roots of *V. erioloba* individuals are unknown, and as such it is assumed that the roots will be of a similar depth of the current ground water table;
- It is assumed that younger individuals will be able to adjust to the changing of the ground water table more rapidly than older individuals.

1.4 Legislative Requirements

1.4.1 National Forest Act (NFA; Act 84 of 1998)

According to the NFA; Act 84 of 1998 a tree permit application should be applied for should any protected tree be cut, disturbed, damage or destroyed, or possess, collect, remove, transport, export, purchase, sell, donate or in any other manner acquire or dispose of any protected tree, or any forest product derived from a protected tree.

1.4.2 National Water Act (NWA; Act 36 of 1998)

The NWA; Act 36 of 1998 recognises that the entire ecosystem and not just the water itself in any given water resource, constitutes the resource and as such needs to be conserved. No activity may therefore take place within a watercourse unless it is authorised by the Department of Water and Sanitation (DWS[1]).

2 LITERATURE REVIEW

2.1 Ground Water Dependant Ecosystems

The sustainable use of groundwater should not only ensure that future exploitation of the resource is not threatened by current overuse, but also that natural resources dependant on the resource is protected (Cook & Lamontagne, 2002). In the past, the management of groundwater was made using the concept of sustainable yield defined as the attainment and maintenance of the long-term balance between the amount of groundwater withdrawn annually and the annual amount of recharge. This approach however fails to recognise that many ecosystems are reliant of ground water in order to properly function. The dependency of ecosystems on groundwater is therefore now included in the definition of sustainable yield in various countries, such as Australia (Lamontange, 2002).

In South Africa, the National Water Act (NWA) of 1998 is based on principles which include water as an undividable national asset, the interdependence of all elements of the water cycle, the importance of the ecological functions of all water, and the need to treat all water consistently in law (DWAF, 1996; Colvin *et al.,* 2002). South African Water Resources are protected through the Resource Directed Measures (RDM) and Source Directed Controls. The role of groundwater to support terrestrial ecosystems of importance, particularly within the semi-arid region of South Africa may be protected through RDMs such as the classification of certain areas requiring special management (Colvin *et al.,* 2002). Aquifer management can be described as the art of abstracting no more water than is replenished, and should take into consideration the ecological reserve as set out in the NWA, which allows for timeous and adequate supply of water to not only maintain the integrity of rivers but also the terrestrial plants reliant on the aquifer (Shadwell and February, 2017).

In order to understand the restrictions to be placed on allocable groundwater, it is important to understand the degree, extent and nature of dependency a vegetation community has on a groundwater aquifer. The degree of dependency can vary from total to seasonal dependency. Even seasonal dependency can be critical and could lead to the demise of an ecosystem if

[1] The Department of Water and Sanitation (DWS) was previously known as the Department of Water Affairs (DWA) and the Department of Water Affairs and Forestry (DWAF). For referencing purposes, the name of the Department under which documentation was published, is used.

groundwater is no longer available. The extent can be localised to widespread, depending on the nature of the water table. A restricted aquifer can however support a keystone ecosystem with an importance greater than its geographical extent. The nature of dependency is more difficult to determine, and will often only be seen once the ecosystem has been stressed beyond its critical threshold. For most ecosystems, the depth to the water table is the most crucial hydrogeological parameter controlling water to the plant. One theory in ecology states that ecosystems will generally use resources in proportion to their availability, as such an ecosystem will develop some form of dependency on areas where ground water is accessible. This dependency will most likely increase as aridity of the receiving environment increases (Colvin *et al.,* 2002).

GDE's do not only play a role in the aesthetic and cultural value of an ecosystem in the landscape, but is also important in preserving biodiversity, flood control and the maintenance of water quality (Lamontagne, 2002). Plant communities dependant on groundwater (phreatophytes) are often similar to wetland plant communities, except that they occur in areas where the water table does not reach the surface. Although most phreatophytes occur in areas with shallow water tables, some phreatophytes can use deeper groundwater, and as such threats to terrestrial GDE's include declining water tables, salinization of groundwater, and drowning due to a rise in the water table. Studies from tree plantations suggests that terrestrial plant communities are more reliant on groundwater that what was previously recognized (Lamontagne, 2002)

The dependency of ecosystems of groundwater is more complex than simply a fixed amount during a given year, but rather the pattern of water usage of four key groundwater attributes (or groundwater regime) will determine the requirements of GDE's (Clifton & Evans, 2001). These attributes include:

- Flow or flux: the rate and volume of groundwater supply;
- Level: for an unconfined aquifer, the depth of the water table below the surface;
- Pressure: for confined aquifers, the potentiometric head of the aquifer and its expression in groundwater discharge areas; and
- Quality: the physico-chemical properties, including temperature, oxygen, pH, salinity, nutrients and contaminants of the groundwater.

According to Lamontagne (2002), the pattern of water usage further includes:

- Thresholds: boundaries within which a given attribute must be maintained;
- Rate of use: How much water and at which rate is it used; and

- Temporal distribution of use: temporal dimension, including timing, frequency, duration and episodicity.

The key attributes that are likely to have a significant impact on a GDE, should they change, will differ from ecosystem to ecosystem, and how a particular ecosystem will respond to a change in an attribute may differ between ecosystems. In some scenarios, the response might be proportional to the change in an attribute, however in another scenario the entire ecosystem might collapse if an attribute is not maintained (Lamontagne, 2002).

Within semi-arid to arid regions, riparian zones are important areas for biodiversity, as it offers refuge and habitat for a variety of organisms. In such areas, non-perennial rivers are often supported by alluvial aquifers, and as such the perennial systems receive a significant amount of local groundwater fed baseflow. In these systems, riparian vegetation often rather relies on groundwater as opposed to surface water flows, and groundwater extraction could therefore have a significant impact on these ecosystems (Colvin *et al.,* 2002).

2.2 Impact of Groundwater Extraction on GDE's

The recharge of an aquifer will be exactly balanced by the discharge under natural conditions. As such, any additional groundwater extraction will upset this equilibrium, resulting in a change in the water table. If the rate of extraction is less than the rate of recharge, a new equilibrium will eventually be recached, where discharge once again is equal to recharge. The time lag between extraction of groundwater and a reduction in natural discharge of groundwater is dependent on the natural discharge and recharge rates, as well as the distance of the extraction points to the natural discharge and recharge zones. In areas where the distance between the extraction point and natural discharge and recharge point is small, the reduction in groundwater levels will be rapid, however where extraction points are located large distances away, there will be a delay in the impact on natural ecosystems (Cook & Lamontagne, 2002).

There is however no level of groundwater extraction, that will not in the long-term result in a decline of natural discharge with some environmental effects. These impacts however could often be small, and not readily identifiable, while in other cases it can be detrimental. As such it is the task of an environmental manager to determine what level of impact to the environment is acceptable, and to manage the extraction in order to maintain these acceptable impact levels (Cook & Lamontage, 2002)

In order to determine the impact that abstraction might have on a particular ecosystem, one must first establish the dependency of the ecosystem on the aquifer. Establishing the dependency of terrestrial vegetation on groundwater is not a simple matter. Measure of vegetation vigour, such as the Leaf Area Index in semi-arid to arid regions, can be an indicator of groundwater availability, indicating that vegetation might utilise water other than rainfall. Another more quantitative approach is the use of sap flow techniques, such as ventilated chambers to measure plant transpiration. If transpiration exceed annual rainfall, it means that the plant community make use of groundwater as an additional water source. A third approach includes that of isotopes to determine the sources of water used by an individual plant, or a plant community (Cook & Lamontage, 2002).

2.3 Vachellia erioloba and its Importance Within a Landscape

V. erioloba was first granted protected status in South Africa in 1941 (Seymour & Milton, 2003), and has again been included on the latest List of Protected Tree Species (GN 809 of 2014) under the National Forest Act (Act 84 of 1998).

V. erioloba is generally restricted to the Kalahari sands formations, mainly associated with the western parts of southern Africa (Barnes *et al.,* 1997). Its range extends from Southern Angola and Namibia, through parts of Botswana, southern Zimbabwe and North West of South Africa (Seymour & Milton, 2003). Acocks (1975), describes *V. erioloba* in South Africa to be generally associated with deep sand over limestone in the flat, hot semi-arid to arid region of the Kalahari thornveld. Over its range, the species can differ greatly in stature from a shrub to a very large tree (up to 15m), depending on rainfall (which varies between < 400mm to 900mm/ year) and the availability of ground water (Barnes *et al.,* 1997).

V. erioloba is adapted to shallow to deep, infertile, sometimes alkaline sands, where it uses its extremely deep roots to access and use deep water containing dissolved nutrients (Seymour &Milton, 2003). Roots have been recorded to be up to 45m (Barnes *et al.,* 1997) and 60m (Seymour &Milton, 2003) deep. These trees are often restricted to sandy soils, where it has the advantage of rapidly extending its roots to permanent ground water, this advantage is not as apparent in heavier soils (Seymour &Milton, 2003). In areas where rainfall is less than 250mm/annum, the presence of *V. erioloba* is said to indicate that ground water is available, where these species depend upon its ability to root to immense depths to gain access to the permanent underground water table. The occasional rainstorm is only required for germination, once the root has formed, it will grow until it reaches permanent water, and the tree can survive on virtually no rain for more than 100 years (Barnes *et al.,* 1997). Although rain is required for germination, a single rainstorm event will not ensure survival of the newly emerged seedlings, and as such in order for seedlings to survive, favourable conditions between 50 and 280 rainfall days are needed for seedling establishment rates of 30 and 64% respectively (Seymour & Milton, 2003)

During the first four to five years, *V. erioloba* are very slow growing above ground, while it develops a very deep root system. After the initial underground growth period, the above ground parts can grow rapidly and can attain a stem diameter of 30cm and 7m in height after another 15 to 20 years (Barnes *et al.,* 1997). The average annual increase in tree radius is in the region of 1.55 mm per year, as such a 9mm increase a year in circumference, with the vertical growth rate of seedlings reported between 300 and 500mm a year (Seymour & Milton, 2003).

The trees start to form flowers, at 10 years of age, and produce regular large pods by age 20 (Seymour & Milton, 2003). *V. erioloba* flowers only once a season, and mainly on the previous year's growth (Barnes et al., 1997). Flowering usually stretches from July to November, with a sharp peak in September (Seymour &Milton, 2003). Once flowering ends in about September, new vegetative growth starts, where branchlets can grow more than a meter in length over the next six weeks, after which the stem and spines thicken. There is no further shoot extension until the following spring (Barnes *et al.,* 1997).

V. erioloba are very long-lived for Acacias, with individual trees reported to reach ages of 300 years. As these trees are relatively free from predators in its old age, its decline takes place over a very long time (Barnes *et al.,* 1997).

As *V. erioloba* are often the only tree of significant size within the landscape, it increases the heterogeneity of the landscape by increasing species richness as it provides habitat and services for a variety of floral and faunal species (Seymour &Milton, 2003). The life cycles of many faunal species are often closely associated with this tree species. The use of these trees by birds and antelope, result in a concentration of nutrients under the canopy, leading to the development of distinctive plant communities (Barnes *et al.,* 1997). As such the loss of this species from the area has a detrimental effect on the entire ecosystem of the region.

As sandy soils have a low water holding capacity, exceptionally severe drought is expected to result in some mortality of the species. Botswana experienced a continuous drought between 1981 and 1987, and the cumulative effects of these years were considered an episodic event. During this period, various tree species succumbed to the drought, however *V. erioloba* was only affected in one area, characterised by compacted calcareous soils. In all other areas where the drought seemed severe, the species survived. Depth of sandy soils influence rooting depth and the likelihood of trees surviving drought, and as such once a tree is over a certain threshold height (or root depth) the species is in principal immune to drought (Seymour &Milton, 2003).

Extraction of water from the Kuiseb River Valley in Namibia, which resulted in a lowering of the water table, had a severe effect on old large *Faidherbia albida* trees, however the effect on young *V. erioloba* individuals was less severe, with its rapidly growing taproot able to more readily adapt to the change of groundwater levels (Barnes *et al.,* 1997).

2.4 Case Studies on the Importance of Groundwater for V. erioloba

2.4.1 Relationship between fog, floods, groundwater and tree growth along the lower Kuiseb River in the hyperarid Namid (Schachtschneider & February, 2010)

Studies in southern Africa have shown that an increase in time between flood events and receding groundwater levels result in increased tree mortality rates, with mortality rates differing between species and age classes (Schachtschneider & February, 2010). Kladia Schachtschneider and Edmund February conducted a study in 2010, to determine the ratio of the various water sources used by three Riverine Species of the Kuiseb River in the Namib Desert, namely *Vachellia erioloba, Faidherbia albida,* and *Tamarix usneoides*. The primary objective of this study was to determine the relationship between tree growth along river courses in hyperarid regions and fog, flood and groundwater (Schachtschneider & February, 2010).

From the results, it was determined that none of these tree species make use of fog water, but are rather reliant on a seasonally fluctuating combination of groundwater, shallow soil water (0-1m) and deep soil water (1.5 – 3m). This study showed (Table 1), that adult *V. erioloba* individuals are mostly reliant on deep soil water, where it contributes 90% of the water source for these trees within the wet season, and 62% during the dry season. Deep soil water contributes the highest percentage (49%) of water to juvenile *V. erioloba* individuals during the wet season, however during the dry season this ratio changes, with groundwater (42%) contributing the highest percentage to these individuals during the dry season. Adults established after the 1974 floods, and were growing within 50m of the active channel while juveniles established after the 2001 flood events and were growing within 30m of the active channel. (Schachtschneider & February, 2010).

Table 1: Ratio of various water sources used by adult and juvenile *V. erioloba* individuals during the wet and dry season (Schachtschneider & February, 2010).

	Groundwater	Shallow soil water (0 – 1m)	Deep soil water (1.5 – 3m)
V. erioloba adult wet	2%	8%	90%
V. erioloba adult dry	30%	6%	62%
V. erioloba juvenile wet	19%	28%	49%
V. erioloba juvenile dry	42%	34%	20%

Recharge of these water sources are dependent on the Kuiseb aquifer recharge during flood events, especially large flood events as has taken place in 1997 (33 days) and 2000 (23 days). Although smaller events also contribute to groundwater recharge, it is not as significant as large events lasting many days, resulting in a steady decline of the water table between large events (Schachtschneider & February, 2010).

The drought in the upper reaches of the catchment between 1980 and 1984, lead to no recharge of the Kuiseb aquifer, resulting in a drop of water levels between 2 and 6m. The trees investigated in this study are so reliant on this recharge, that drought related deaths accounted for 29% of *V. erioloba* individuals, 24% of *T. usneoides* and 62% of *F. albida* (Schachtschneider & February, 2010). As all three species make use of the same water sources, although in varying ratios, this indicates that mortality is not related to rooting depth, however other studies has indicated that *V. erioloba* is drought tolerant through deep rooting and track changing water tables (Schachtschneider & February, 2010; and Colvin *et al.,* 2002), whereas *F. albida* cannot tolerate drought. As such, vegetation structure along ephemeral rivers will become seriously threatened should aquifers decline substantially as a result of increased water abstraction and global climate change (Schachtschneider & February, 2010).

2.4.2 Effects of groundwater abstraction on two keystone tree species in an arid savanna national park.

An increase in tourism in the Kgalagadi Transfrontier Park, has resulted in an increase in groundwater abstraction, as there is no natural surface water flow within the Park. Previous studies have shown that an increase in tourism in arid environments can result in both the short and long-term decline of the underground water table, with a subsequent negative influence on groundwater dependant ecosystems (Shadwell and February, 2017). Shadwell and February conducted a study to determine the effects that groundwater abstraction will have on the vegetation structure of arid regions with no surface water flow.

The dominant species in the dry river beds at the Auob and Nossob Rivers study sites were *V. erioloba and V. haematoxylon.* These were the only large trees, with scattered smaller trees and bushes, and dwarf shrubs and grasses scattered in sparse clumps. Both these trees are considered keystone species within the ecosystem as they provide, food, shade, nesting sites and soil nutrients for a variety of other plants and animals (Shadwell and February, 2017).

The authors determined the interaction between groundwater and the two-tree species mentioned above. The method used is based on the assumption that the stable isotope ratio in xylem of non-photosynthetic tissue will be the same as the water source. As such they determined the water source of the tree species measuring the hydrogen and oxygen isotope ratios in both the bore hole water and the xylem vessels of the tree species. Secondly, they determined to which extent the trees are physiologically stressed by measuring the stable carbon isotope ratios of the leaves, the xylem pressure potential at midday, the specific leaf area as well as canopy death (Shadwell and February, 2017).

Samples were taken at four boreholes, one sampling point upstream, and one point downstream of the extraction boreholes on both the Auob and the Nossob Rivers, namely the Urikaruus waterhole (upstream) and Kamqua waterhole (downstream) of the Urikaruus Wilderness camp borehole in the Auob River, and the North Kwang (upstream) and Qubit'je Quap borehole (downstream) of the Nossob camp borehole in the Nossob River. Both *V. erioloba* and *V. haematoxylon* area dominant in the Auob River, and as such six trees of each species were sampled at both the upstream and downstream sites. In the Nossob River, the only large trees were *V. erioloba,* and 8 trees were sampled at both the upstream and downstream sites (Shadwell and February, 2017).

With the use of piezometers at all the sampled boreholes, it was determined that the depth to the aquifer varies between 38m and 59m (Auob: 38m – 46m; and Nossob: 49m -59m), with the upstream water table lower than the downstream study site for both Rivers. This is speculated to be a result of a calcrete layer close to the surface underlying the downstream boreholes in both rivers. Within the Auob River there was an approximate 4m drop in the water table soon after the peak of the dry season, with a subsequent 4m rise after the wet season rains. Within the Nossob River however the water level dropped by 6m two months after the peak of the dry season, with only a 2m rise during the peak of the following wet season (Shadwell and February, 2017).

Stable water isotope analysis further indicated that these trees make use of this water source. The Auob River extraction borehole is considered to be a low water use site, while the Nossob

is considered to be a high-water use site. Differences in water use of trees at these two sites were observed during the study (Shadwell and February, 2017).
In the Auob, both tree species make use of this groundwater source during the wet season, however during the dry season only trees at the upstream point used this groundwater, while trees at the downstream sites used more isotopically enriched soil water, as they start to lose contact with the groundwater source. The study also showed that trees at the downstream site have adapted physiologically to the change in water availability by producing heavier smaller leaves with marginally more negative Xylem Pressure Potential (XPP) (Shadwell and February, 2017).

V. erioloba in the Nossob also uses groundwater in the wet season, however during the dry season trees at both the upstream and downstream site used the more isotopically enriched soil water with smaller heavier leaves. The significantly more positive ^{13}C isotope values for the downstream trees suggests that these trees maintain leaf water potential through closure of the stomata resulting in a significantly more negative XPP, to prevent damage to xylem tissue. As such the trees in the Nossob is considered to be under significantly more stress due to a change in available water (6m drop in dry season, only 2m rise in the following wet season).

The trees near the Nossob camp showed signs that the drop in groundwater levels due to higher abstraction rates has exceeded thresholds identified by studies conducted in America and Australia as being critical. Although the decline in the groundwater level at this site was not as much as seen in the studies in Australia and America, the water column in trees in the Nossob are under greater negative pressure due to the depth of the water table (40-60m) as opposed to the 5m within the American South West (Shadwell and February, 2017). Although the trees at the downstream site in the Nossob River controlled water loss through stomatal regulation, such stomatal regulation in a drought event can result in carbon starvation, canopy die back and canopy death (Shadwell and February, 2017).

2.5 Literature review conclusion and implications for the particular study

V. erioloba is a keystone species in arid and semi-arid environments such as the Northern Cape Province of South Africa, and as such also the study area. As the rainfall in these areas are normally low and highly seasonal, these trees often have to rely on an alternative water source other than rainfall for large portions of the year. These trees are also exceptionally deep rooted, allowing them to access groundwater to depths up to 70m below the surface

(Schachtneider and February, 2013). From the studies discussed in Section 2.4, it was determined that *V. erioloba* trees showed severe physiological stress during a permanent lowering of the groundwater table by 4m in a single year. *V. erioloba* does however possess the ability to track changes to the water table to some degree, particularly juvenile trees, and as such it is believed that juvenile trees should be able to recover to such changes more readily than mature trees. As such, it is expected that canopy dieback of mature trees will start to occur in areas where the water table will be permanently lowered by more than 4m over the course of the mining process.

The *V. erioloba* trees associated with the study area are likely to make use of the upper Kalahari Aquifer (average thickness 80m) associated with the study area (SLR, 2013), although abstraction will take place from the deeper lying Dwyka Aquifer (average thickness 200m). As per the hydrological report, there is very little to no interaction between these two Aquifers, no significant groundwater contribution to baseflow of the Kuruman River is evident and no significant impact on the shallow Kalahari Aquifer is likely. Thus, any impact on ADE is highly unlikely due to dewatering effects and as such, the impact on the Kalahari Aquifer as a result of dewatering is considered to be insignificant (SLR, 2013). For this reason, the *V. erioloba* ADEs falling within the anticipated cone of the depression are unlikely to be influenced by the mining operation.

3 FIELD ASSESSMENT RESULTS

A single field assessment was undertaken in August 2017 within the simulated maximum cone of depression, during which time the presence of *V. erioloba* trees and other potential species likely to make use of groundwater were determined. During the field assessment, the presence of large *V. erioloba* individuals were confirmed, with *V. haematoxylon* individuals also encountered. The majority of large individual trees were associated with the western side of the Kuruman River, as indicated in Figure 3 below.

Figure 3: Large *V. erioloba* individuals situated on the western side of the Kuruman River.

A geohydrological report was compiled by SLR (2013) for the Lehating Mine situated on Portion 1 of the Farm Lehating 741 and Portion 2 of the Farm Wessels 227. These are two of the farm portions included in the study area, with a large portion of the cone of depression affecting this area. According the SLR (2013) geohydrological report, the surface geology of the area falls within the Kalahari formation which is extends from surface level to approximately 80m deep. Furthermore, it was confirmed with local landowners that boreholes within the study area are generally around 6m deep and that the groundwater level within the Kuruman River is just below the surface. The Kalahari Aquifer therefore forms part of this upper geological layer.

It is therefore highly likely that trees in the area, reliant on ground water will make use of the Kalahari Aquifer, as roots of these species have been recorded deeper than 60m. This report further states that the iron and manganese bands to be mined falls within the Hotazel formation, which is overlain by the Dwyka formation (200m deep), containing the deeper lying Dwyka Aquifer, which will be subject to dewatering during the mining process. This report further stipulates that the impact as a result of dewatering of the Dwyka Aquifer for mining purposes will be insignificant on the shallow Kalahari Aquifer likely to be utilised by the ADEs. As such, it is highly unlikely that the ADEs associated with the study area will be impacted during the mining operation.

As all of the aspects above are highly theoretical, it is suggested that monitoring of *V. erioloba* populations does take place to ensure that mining activities do not negatively affect these ADEs. Monitoring areas were identified during the field investigation, and divided into priority classes, by identifying areas where large *V. erioloba* populations were present (Figure 4). As Monitoring Priority Area 1 falls within the cone of depression where water drawdown will be the highest (20 to 44m), it is suggested that monitoring start within this area. Should any negative impact be observed on these trees, it is suggested that Monitoring Priority Area 2 (16 to 40m) be included in the monitoring programme. Monitoring Priority Areas 3 (0 to 4m) only need to be included within the monitoring programme if any negative impacts are observed within Monitoring Priority Area 2.

During the site assessment, it was observed that a large number of *Prosopis glandulosa* individuals were associated with the area, particularly within the riparian zone of the Kuruman River. According to a study conducted by Schachtschneider and February in 2013 there was a 50% increase in *V. erioloba* canopy die back in river plots where *Prosopis* invasion was present, as oppose to those where *Prosopis* has been removed. This is due to both species having deep rooted systems, and therefore making use of the same water source. Prosopis not only comprise of a deep rooted taproot (recorded up to 53m), but also an extensive lateral root system, *Proposis* is able to take up sparse precipitation by growing outward an upward to within 5 cm of the soil surface, as well as utilising deep groundwater. The high transpiration rate of *Prosopis,* further result in a rapid decline of the water table. *V. erioloba* is unable to develop new roots fast enough to access water of the receding eater table. As such their study strongly supports the removal of *Prosopis* from rivers in arid parts of Southern Africa (Schachtschneider and February, 2013). As such it is advised that all *Prosopis glandulosa* individuals associated with the Kuruman River falling within the anticipated cone of depression be removed. This will have a positive impact on any ADEs within the zone of influence as more water will be available in the landscape for any possible ADEs.

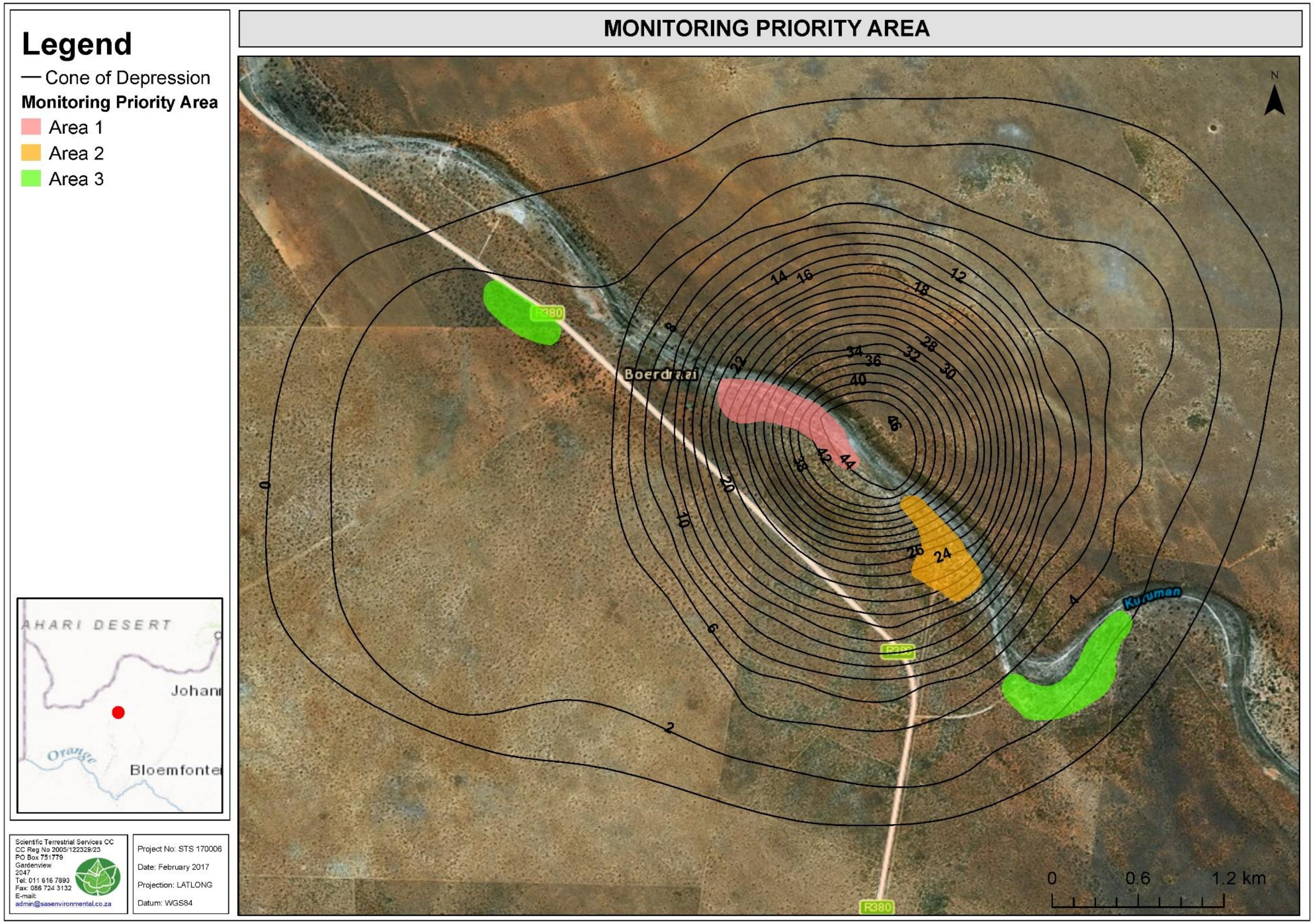

Figure 4: Monitoring Priority Areas

4 *V.* ERIOLOBA MONITORING OBJECTIVES AND PROTOCOL

4.1 Monitoring Objectives

- A wet and a dry season monitoring assessment should be undertaken prior to the commencement of dewatering, in order to establish baseline conditions during both the wet and dry season;
- During the first three years of the operation, monitoring should take place twice a year, during both the wet and the dry season;
- Should no effect on these trees be observed during the first three years of the operation, monitoring should continue once yearly for the next five years, during the dry season;
- If no negative effect is observed on these trees during the five year, annual monitoring period, monitoring can be performed once every two years, for the remainder of the operation, as well as for the first five years after decommissioning and closure, to ensure no there was no delay in the effect on these ADEs;
- Should it be determined at any time during the monitoring process that the trees are undergoing stress as a result of the mining operation, an irrigation protocol (such as irrigating trees with perforated subterranean pipes or drip irrigation systems) should be established, and monitoring should be done every six months for the remainder of the operation, as well as for 8 years post decommissioning and closure. Should these trees still be under stress at the end of the 8 year period, further monitoring should be implemented.

4.2 Monitoring Protocol

- It is important to establish the water level of the aquifer during various seasons, this can be established by installing Piezometers in Kalahari Aquifer extracting boreholes in the area where monitoring is to take place;
- In the initial stages of monitoring, trees can be qualitatively monitored through visual observation for any sign of moisture stress, such as new leaves being smaller in size as compared to pre-dewatering conditions or wilting/dying. Should the trees be suspected to be under moisture stress, more elaborate stress testing should be conducted as specified below.
- In order to quantitatively determine plant moisture stress the following methods can be utilised:

- Stable carbon isotope ratios of plant leaves can be used to determine the efficiency of carbon assimilation in plants and as such plant water use. The principle is that when plants are stressed, they regulate water lost by closing their stomata. As the stomata close, less carbon is assimilated, and a lower discrimination against the heavier ^{13}C isotope, resulting in a more positive δ^{13} C value;
- Oxygen and Hydrogen stable isotope analysis can be conducted on water extracted from non-photosynthetic xylem tissue, as well as rain water, soil water and groundwater, to determine the main water source of these plants during different seasons;
- By measuring the Xylem Pressure Potential (XPP). XPP indicate the amount of water available to the plant, by determining the amount of pressure the water column in xylem tissue of the plant is under; and
- Measuring the specific leaf area (the ratio of leaf area to leaf dry mass) of the plants. As soil moisture decreases, the specific leaf area of the plant will also decline, as leaves become smaller and heavier to reduce water loss. This includes photographing whole leaves against a white background, and then using an open source software such as Image J to determine the leaf area.

5 CONCLUSION

Scientific Terrestrial Services (STS) was appointed to conduct an investigation into the dependency of *Vachellia erioloba* and *Vachellia haematoxylon* trees on ground water resources, as well as the effect of ground water extraction and Aquifer Dependent Ecosystems (ADEs) for the proposed Khwara mine, near Hotazel, Northern Cape.

Following the field visit, an analysis of a geohydrological assessment for the mine and extensive literature review, no significant impact is anticipated on the shallow Kalahari Aquifer which is possibly utilised by ADEs, no significant groundwater contribution to baseflow of the Kuruman River is evident. Thus, any impact on ADE is highly unlikely due to dewatering effects and as such, the impact on the Kalahari Aquifer as a result of dewatering is considered to be insignificant. For this reason, the ADEs falling within the anticipated cone of depression are unlikely to be influenced by the mining operation.

As all of the aspects above are highly theoretical, it is suggested that monitoring of *V. erioloba* populations is undertaken according to the protocols and objectives as stipulated in this report. Furthermore, it is recommended that *Prosopis glandulosa* individuals associated with the

Kuruman River falling within the anticipated cone of depression be removed. This will have a positive impact on any ADEs within the zone of influence as more water will be available in the landscape for any possible ADEs.

It is the opinion of the specialists that, should the management and monitoring protocols as set out in this document be implemented, no adverse impacts on ADEs within the study area are likely.

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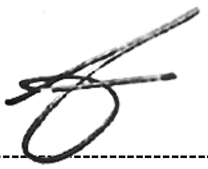
APPENDIX A – DECLARATION AND SPECIALISTS CV'S

<u>Declaration</u>

Declaration that the specialist is independent in a form as may be specified by the competent authority

I, Emile van der Westhuizen, declare that -

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



Signature of the Specialist

SCIENTIFIC TERRESTRIAL SERVICES (STS) – SPECIALIST CONSULTANT INFORMATION

CURRICULUM VITAE OF EMILE BASSON VAN DER WESTHUIZEN

PERSONAL DETAILS

Position in Company	Ecologist, Botanist
Date of Birth	30 May 1984
Nationality	South African
Languages	English, Afrikaans
Joined SAS	2008

MEMBERSHIP IN PROFESSIONAL SOCIETIES

Member of the South African Council for Natural Scientific Professions (SACNASP) (Reg. Number 100008/15).

EDUCATION

Qualifications	
BSc (Hons) Plant Science (University of Pretoria)	2012
B.Sc. Botany and Environmental Management (University of South Africa)	2010
Short Courses	
Grass Identification – Africa Land Use Training	2009
Wild Flower Identification – Africa Land Use Training	2009

COUNTRIES OF WORK EXPERIENCE

South Africa – Gauteng, Mpumalanga, North West, Limpopo, KwaZulu-Natal, Free State, Eastern Cape.
Mozambique (Tete, Sofala and Manica Provinces)
Sierra Leone
Angola (Zaire and Cabinda Provinces)
Democratic Republic of the Congo (Katanga and Kivu Provinces)
Ghana (Western and Greater Accra Provinces)

SELECTED PROJECT EXAMPLES

Floral Assessments

- Floral assessment for the proposed Modikwa Platinum Mine South 2 Shaft Project, Burgersfort, Limpopo Province.
- Floral assessment for the proposed New Clydesdale Colliery Stoping Project, Vandyksdrift, Mpumalanga Province.
- Floral assessment as part of the EIA process for the proposed Harriet's Wish PGM Project, Limpopo Province.
- Floral assessment as part of the environmental authorisation process for the proposed Shanduka Coal Argent Colliery in the vicinity of Argent, Mpumalanga.
- Floral assessment for the Auroch Resources Manica Gold Mining Project, Manica, Mozambique.
- Floral assessment for the Namoya Gold Mine project in Namoya, Democratic Republic of Congo.
- High level floral risk assessment and alternatives analysis for the proposed new Tete Airport, Tete, Mozambique.
- Floral assessment for the proposed Richardsbay Harbour Compactor Slab development, Richardsbay, Kwa-Zulu-Natal Province.
- Site walkdown and floral ecological input prior to the construction of the proposed 180km Mfolozi-Mbewu powerline, Richardsbay, Kwa-Zulu-Natal Province.
- Floral assessment as part of the EIA process for the proposed Peerboom Colliery, Lephalale, Limpopo Province.
- Floral assessment as part of the EIA process for the proposed Overvaal Underground Coal Mine Project, Ermelo, Mpumalanga Province.
- Floral assessment as part of the EIA process for the proposed King's City Takoradi 3000-hectare development, Takoradi, Ghana
- Floral assessment as part of the EIA process for the proposed Aquarius Platinum Fairway Platinum Mine, Steelpoort, Mpumalanga Province.
- Floral assessment as part of the EIA process for the proposed Geniland Lubumbashi City 4000-hectare development, Likasi, Katanga Province, Democratic Republic of Congo.

- Floral, faunal, aquatic and wetland assessment as part of the EIA process for the proposed Appollonia City Accra 3000-hectare development, Accra, Ghana.
- Floral assessment as part of the EIA process for the proposed Leeuw Colliery, Utrecht, Kwa-Zulu Natal Province.
- Floral assessment as part of the EIA process for the proposed Lubembe Coppermine Project, Lubumbashi, Katanga Province, Democratic Republic of Congo.
- Floral assessment as part of the EIA process for the proposed Kinsenda Coppermine Project, Lubumbashi, Katanga Province, Democratic Republic of Congo.
- Floral assessment as part of the EIA process for the proposed Lonshi Coppermine Project, Lubumbashi, Katanga Province, Democratic Republic of Congo.
- Floral assessment as part of the EIA process for the proposed Jozini Shopping Mall, Jozini, Kwa-Zulu Natal Province.
- Floral assessment as part of the Biodiversity Action Plan for the Assmang Chrome Dwarsrivier Mine, Steelpoort, Mpumalanga Province.

SCIENTIFIC TERRESTRIAL SERVICES (STS) – SPECIALIST CONSULTANT INFORMATION

CURRICULUM VITAE OF MARELIE MEINTJIES

PERSONAL DETAILS

Position in Company	Junior Field Biologist
Date of Birth	8 July 1986
Nationality	South African
Languages	English, Afrikaans
Joined SAS	April 2015

EDUCATION

Qualifications

MSc Medicinal Plant Science (University of Pretoria)	2014
BSc (Hons) Medicinal Plant Science (University of Pretoria)	2012
BSc Biotechnology (University of Pretoria)	2011

COUNTRIES OF WORK EXPERIENCE

South Africa – Gauteng, Mpumalanga, Free State, Northern Cape, Western Cape

SELECTED PROJECT EXAMPLES

Terrestrial Assessments

- Vegetation Screening Assessment for the Bloekombos Ext 3 development within the Western Cape Province.
- Floral Ecological assessment for the Jeannette Expansion Project at the Taung Gold International Mine near Welkom, Free State Province.
- Terrestrial Sensitivity Scan as part of the environmental impact assessment and authorisation process for the proposed development of a pipeline in Kriel, Mpumalanga Province.
- Floral Ecological Scan as part of the Environmental Impact Assessment and authorisation process for the proposed Northriding Holding 470 development project, Gauteng Province.
- Terrestrial Ecological Scan as part of the S24G rectification process for the unauthorised activities that has taken place on portion 1 of the remaining extent of portion 4 of the farm Vlakfontein 69 IR within Benoni, Gauteng Province.

Wetland Assessments

- Wetland Rehabilitation and Management Plan for the wetland and open space area associated with the Carlswald Valley Residential Development, City of Johannesburg, Gauteng Province.
- Riparian Zone Ecological Assessment as well as a Riparian Rehabilitation and Management Plan for the proposed maintenance activities associated with the LC de Villiers Sports Campus of the University of Pretoria, Gauteng Province.

Desktop Ecological Assessments

- Desktop Ecological Assessment as part of the environmental assessment and authorisation process for the Genet Manganese (Pty) Ltd prospecting area on the farm Lemoenkloof No 456, Northern Cape Province.

Water Use Applications

- General Authorisation Application Process to obtain authorisation from the Department of Water and Sanitation for the water uses related to the proposed road upgrades associated with the Pearl Valley Phase II Development, Paarl, Western Cape Province.