Cradle of Humankind World Heritage Site

THE MANAGEMENT OF KARST LANDSCAPES AND CAVES

FINAL REPORT

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1 EXECUTIVE SUMMARY

- There are numerous valid reasons for protecting and managing the subterranean environment of the Cradle of Humankind World Heritage Site. These encompass ecological, water conservation, scientific, commercial, tourism and aesthetic aspects.
- Although protective legislation exists, this often
    - is difficult to enforce and monitor
    - presents gaps
    - overlaps and duplicates areas of responsibility
    - is not co-ordinated, enforced, policed and monitored by any one organ of state.
- The subterranean environment and the intricate and fragile “biosphere” it contains is an overlooked and under-managed ecological area.
- The Minerals Act, the National Water Act, the National Heritage Resources Act, the National Environmental Management Act, the Tourism Act, the Public Health and Safety Act and the Nature Conservation Ordinance 12 of 1983 all impinge on cave management and cave users.
- A number of sensitivities, risks and threats to the subterranean environment have been identified. The most significant of these is a lack of co-ordinated management which allows uncontrolled human activities to cause on-going degradation of this environment.
- A number of threats and risks to cave users have also been identified, the most important of these being site safety and the risk of contracting Histoplasmosis, particularly for HIV positive people.
- No adequate measures are in place to control the depredations caused by commercial operators and other cave users. Serious environmental depredation has been caused over the last decade with the rise in popularity of “adventure sport” - caving and cave diving.
- Private landowners use or abuse the subterranean environment as they please: for dumping waste and dead animals, allowing uncontrolled commercial operations or excessive groundwater abstraction. Pollution of groundwater by domestic sewage is also a problem.
- The effects of human activities can be gauged by diminishing evidence of wintering bat colonies in the Cradle of Humankind World Heritage Site caves. The Schreiber’s Long-fingered bat *Miniopterus schreibersii* appears to have declined to a point of concern.
- New satellite-borne magnetometry will shortly render non-disclosure as a management tool ineffective. Information on the whereabouts of subterranean voids will become available on the Internet. This will place a substantial strain on managing and monitoring the resource.
- There is an urgent need for the following management structure: A Karst Institute of South Africa or at least a Karst Committee for the Cradle of Humankind World Heritage Site, dedicated to the protection and management of Karstic landscapes as a whole, as well as to the subterranean environments hosted by the dolomite. This could be one of a number of task-specific sub-committees of the Overall Management Authority.
- Its brief would be to function as a protection, management, policy- and legislation-enforcing, policing, monitoring, co-ordinating and permitting body overseeing all aspects of Karst landscape management in the Cradle of Humankind.

Such a management authority could:

- Identify sites in need of special protection
- Develop a total catchment management plan
- Develop appropriate processes for management planning and produce a Karst management plan
- Develop specific strategies e.g. water quality, fire management or visitor management programmes
- Generate environmentally sound development plans for caves and other tourism attraction in Karst areas
- Train and develop staff skills in Karst management.

- Such a body could not function without:
    - permanent access to professional expertise on all aspects of Karst management
    - knowledgeable and well-trained monitors
    - an inventory or register of caves, including details of locality, name and landowner
    - a database of information pertaining to such caves, e.g. underground surveys, presence/absence of bat colonies, presence of fossils etc.
    - the definition of acceptable criteria to define cave quality in a system of grading from Code I (pristine) to Code 4 (forfeit cave).
    - a priority ranking of caves in order to establish
        a) caves which require protection for their pristine qualities
        b) caves which require protection for their scientific significance
        c) caves which lend themselves to limited specialist access and
        d) caves which are suitable for use as educational and tourist caves.
    - a means of protecting scientifically valuable and pristine caves form the effects of human activities
    - funding to implement protective interventions and Heritage Site monitors or rangers to patrol and control.
- A long-term cave clean-up and rehabilitation programme needs to be instigated.
- The expertise and knowledge of Gauteng's two (rival) caving associations CROSA (Cave Research Organisation of South Africa) and SASA (Speleological Association of South Africa) needs to be acknowledged and enlisted by inviting representatives to participate in a policy-making body in order to draw up
    - a Code of Conduct - including operational guidelines - for commercial operators,
    - a Subterranean Ecology Guidelines document for landowners, researchers, and all cave users,
    - a behavioral Code of Conduct for cavers, tourists, researchers and other cave users,
    - A Subterranean Environment Monitoring Document detailing criteria for monitoring the health of subterranean environments, in the geological, hydrological and biological sense.
    - a subterranean sampling protocol covering geological, sedimentary, vadose and phreatic water and biota sampling, i.e. those areas not covered by SAHRA legislation (N.B. SAHRA's legislation with regard to sampling is deficient: see text and Management of Research and Researchers, Overall Cultural Heritage Management Plan),

    - a cave rehabilitation programme,
    - a Cave Rescue Organization which would include experienced cavers and cave divers,
    - a set of criteria and conditions governing the granting of permits for various categories of cave use,
    - a suggested means of policing and monitoring caves.
- Since the significance of the subterranean environment covers archaeology, palaeontology, groundwater ecology, microbiology, atmospheric physics, geohydrology, education, tourism, climatology, sedimentology, cave geology and cave ecology, representatives of all these disciplines would need to serve on the Karst Management structure.
- The commercial exploitation of “Pelindaba Stone” (chert and stromatolite-rich dolomite) is causing environmental damage and needs to be controlled.
- The legal notion that: "to warn people (of cave dangers) is to admit risk, and to admit risk is to accept responsibility" needs to be clarified for those soliciting paying customers.
- This document should be seen as a first attempt to bring together as many key issues as possible relating to Karst and cave protection. A considerable proportion of the Gauteng province is underlain by Karst, and it is of crucial importance that the long-neglected subterranean environment receives protection, management and attention at the highest level.

2 INTRODUCTION

This report is focused on the overall management of Karst landscapes and caves within the Cradle of Humankind World Heritage Site. Site-specific issues pertaining to the 13 key fossil sites are dealt with in the subterranean ecology reports of the Site-specific Management Plan. The aim of the management strategy proposed in this report is to prevent and control any further degradation of the heritage value of the caves in the Cradle of Humankind World Heritage Site Karst landscape. Damage to these resources is already considerable. In addition to maintaining and preserving such sites, the focus is on correcting the negative effects of past mis-management or lack of management. Some rehabilitation procedures are outlined.

This report is supported by data drawn from the publications and thesis of the late F.N. Gamble, the National Cave and Karst Research Institute report to the Congress of the USA and the World Commission on Protected Areas (WCPA) Guidelines for Cave and Karst Protection (an IUCN document) as well as by data drawn from field studies, experience and observation.

The Karst Management Plan attempts to encompass all elements of international best practice applicable to dolomitic cave management. It incorporates the legal requirements of the Environmental Management Act, the National Water Act, the National Heritage Resources Act, the Tourism Act, the Public Health and Safety Act and the Nature Conservation Ordinance 12 of 1983. It would appear that there are considerable areas of overlap in these legislation fields.

The management plan takes into consideration the fact that the Cradle of Humankind World Heritage Site caves are predominantly of the “Sack Type”, that is, caves with one main entrance and a low ventilation turnover. This has several ecological implications as well as placing a restriction on visitor numbers and frequency of visits.

While preservation and conservation of these fragile subterranean environments is of prime concern, it is realized that a balance between conservation and meaningful exposure and usage needs to be struck. It is only through education and exposure that these caves can be preserved in the long term.

3 CAVES AS HERITAGE

There are numerous reasons for the protection of dolomitic caves. Some of these include:

- caves function as a habitat for endangered and other species of flora and fauna. In the Cradle of Humankind World Heritage Site hyaenas, leopards, porcupines, owls and a variety of other birds, several species of bats and a host of insects and other invertebrates are known to utilize caves.
- caves are important as sites containing examples of rare minerals and crystal forms, as well as unusual solutional features and landforms in their vicinity.
- caves are important as scientific sites for the study of geology, geomorphology, palaeontology and archaeology.
- caves are important as the repositories of palaeontological and archaeological relics: fossil bones and stone tools have accumulated in them. The entire significance of the Cradle of Humankind World Heritage Site derives from this fact.
- caves are important as modern analogues for past processes: the “modern“ dolomitic caves of the Cradle of Humankind provide a living example of the processes of sedimentation (cave filling), consolidation, calcification, decalcification, collapse and erosion. Such processes were also responsible for producing the famous fossil sites, which represent the erosional remnants of former ancient cavern systems and their contents.
- caves are often culturally important sites, both historic and prehistoric, e.g. Uitkomst Cave.
- caves function as spiritual or religious venues.
- caves may be used for specialized agriculture and industries, e.g. cheese-making, mushroom growing, wine cellars, etc. (not in Gauteng at present).
- caves are important as a means of studying and understanding the regional hydrology.
- caves are sources of economically important materials, e.g. travertine (limestone) and bat guano (Sterkfontein, Gladysvale).
- caves provide sites of beauty, mystery, excitement and challenge and are thus important resources for discovery and recreation.
- caves are therefore important for tourism and its associated economic benefits, e.g. tourist caves, scuba diving, caving experiences - Sterkfontein, Wonder Cave, Bat Cave and many others.
- Users of caves are as multifarious as the reasons for preserving caves, making management many-sided and complicated.

4 THREATS AND RISKS TO CAVES AND KARST

There are a wide range of threats and risks to caves and karst, as follows:-

4.1 Fragility of cave ecosystems

1. Cave environments are a delicate balance between moisture levels, relative humidity, gases and gaseous exchange, subtle air movements, temperature variations, substrate conditions and a highly specialized cave biota. This finely-balanced ecosystem is extremely fragile and loss or damage to any one element has a knock-on effect which may contribute to an environmental disaster, impacting on the cave biota or the geohydrological processes or both.
2. Caves are home to many cave-dwelling creatures (troglodytes) as well as many organisms that are dependent on caves for shelter, although they might feed outside the cave (troglophiles). Disturbance through visitation often displaces such fauna.
3. Caves have a very low nutritional status, and cave life is largely dependent on the energy source provided by bat and cave cricket guano, the high moisture levels and the slow geological degradation and accretion processes that are all in a critical balance with other factors such as CO_2 levels, relative humidity, radon emission etc.

4.2 Destructive processes

- Opencast quarrying operations, such as those carried out at Bolt's Farm, can result in culturally significant caves being mined and bulldozed out of existence.
- Engineering threats such as road cuttings, submergence through dam building and filling with debris and waste (e.g. several shafts at Drimolen).
- Mining operations such as the exploitation of floor and roof travertines (limestone) of the ancient Cradle of Humankind caverns and the systematic "harvesting" of speleothems in, for example, the Sterkfontein Tourist Cave, also pose threats and diminish significance. (However, it was the mining operations of the early part of the 20th century that exposed the fossils - even "Little Foot" - in the first place!) Such mining is no longer occurring.

4.3 Major land disturbance

- Changes in soil cover, erosion.
- Changes in vegetation cover.
- Removal of 'sculptured' rocks, i.e. those that are attractively ribbed with chert layers, those that contain stromatolites, those which are attractively weathered with 'elephant skin' surface or which show 'karren'. It is apparent, particularly at the Sterkfontein, Coopers and Kromdraai sites, which are close to an access road, that almost every loose dolomitic rock of portable dimensions has been removed for decorative garden stone. Known as "Pelindaba Rock", this resource is exploited commercially and many tons have reportedly been removed from the Gondolin and Haasgat area.
- The effect of large scale removal is to remove the microhabitats necessary for a wide range of biota such as land molluscs (snails), insects, scorpions, lizards, snakes and plants such as hardy ferns which often establish in the cooler crevices between rocks.
- A second effect is to substantially increase ambient temperature: a covering of rocks of different size and orientation creates a mosaic of shady cooler areas throughout the day. The removal of this textured and varying shady/cool sunny/hot surface raises the ambient temperature. Plants and animals which require a rocky habitat for shelter, protection and survival will die out.

4.4 Hydrological disturbance, groundwater abstraction

- Siltation of waterways - even from activities outside of the actual Karst landscape.

- Diversion or changes in waterflow, e.g. Blaauwbank stream and wetland.
- Excessive groundwater abstraction. Voids in the country rock which are kept stable by being water-filled are destabilized by becoming progressively drained by groundwater abstraction, giving rise to subsidences and sinkholes.

4.5 Pollution of aquifers

- The fissured and faulted permeable dolomitic country rock functions as a natural sponge. The movement of pollutants in groundwater is rapid and difficult if not impossible to contain. Many examples of problems due to groundwater pollution have been documented, amongst the earliest being the 1854 cholera epidemic in Britain. The same could happen here.
- The comparatively rapid transmission of groundwater flows in Karst provides little opportunity for natural filtering or other purifying effects, and problems such as disease transmission may arise much more readily than in other terrain.
- For this reason, only sealed-tank sanitation systems should be permitted in the dolomitic areas of the Cradle of Humankind.
- Sources of pollution located far outside the Karst area itself can still have devastating impacts.
- Sewage effluent from the Krugersdorp/Mohale Municipality's sewage works is pouring into the top (southern) end of the Cradle of Humankind at the rate of approximately 5.7 million cubic meters per annum, via the Blaauwbank River, which flows past Sterkfontein, Swartkrans and several other Cradle of Humankind localities. On occasion, the effluent is noticeably odiferous.
- The proliferation of high-nitrate requiring industries along of the Blaauwbank Spruit, such as vegetable farming, is likely to cause chemical and organic pollution.
- There is a risk of pollution by gaseous hydrocarbons from fuel storage or waste sites.

4.6 Farming, feedlots and fish

- Several intensive farming feedlots have been established within the 100 year floodplain of the Blaauwbank Spruit in the Sterkfontein Valley. Fields have been turned where wetlands with reedbeds were once present. Not only does wetland ploughing destroy the habitat and the natural filtration capacity of wetlands, it also causes siltation of the waterway and damage to riverine habitats downstream. Effluent from the feedlots and the piggery upstream of Swartkrans are responsible for pollution.
- Untreated water from the trout farm on the Blaauwbank discharged back into the river raises the nitrate level as a result of the fish-feeding programme. Introduction of fish-borne diseases present a potential hazard to indigenous fish in the lower Blaauwbank system.

4.7 Human utilisation of caves

- In the COH WHS, human utilisation of dolomitic caves has mainly taken the form of mining (to varying degrees, at all 13 of the key fossil sites), quarrying for aggregate and flux (Bolt's Farm), tourism (Sterkfontein Caves, Wonder Cave), guano extraction (Sterkfontein Cave, Gladysvale), caving and scuba diving (numerous), and scientific research (many sites).
- Speleothem "harvesting" was also practised at many sites, including Sterkfontein, permanently diminishing its tourist value.

4.7.1 The constraints on utilisation imposed by cave form in the COH

4.8 Caves in the Cradle of Humankind are commonly of the "sack" type - that is, the volume of the cave extends below a single main entrance, although the forms of individual caves may vary considerably. There may be smaller subsidiary openings to the surface.

- Such a single-entranced "sack" cave might take on the form of a bottle-necked cave (generally inaccessible, except to cavers), where the entrance is more or less centrally situated over the void, or a vertical or inclined shaft-type entrance might be situated to one side of the cavern chamber.
- The sack situation creates a trap for most gases that are heavier than air i.e. carbon dioxide, ammonia, methane etc.
- Ventilation turnover in sack caves is slow with a large recovery period after disturbance. This slow ventilation has serious implications for visitor numbers and visitor frequency.

4.8.1 Human impacts on caves

Human utilisation of caves results in a wide range of impacts:

- Alteration of the physical structure of the cave by widening passages and creating entrances, e.g. Sterkfontein, Wonder Cave. This has a number of follow-on impacts, such as on air movement, temperature and humidity.
- Alteration of air movements and micro-climate. This affects cave humidity and speleothem growth.
- Alteration of water chemistry. This impacts on speleothem formation and survival of rare isopod populations in some subterranean lakes. The latter are also drastically impacted upon by increased siltation.
- Alteration of cave hydrology, e.g. Wonder Cave and Sterkfontein. From time to time water has to be pumped out to allow for visitor access.
- Introduction of artificial light. This encourages algal and slime mould "blooms", which disfigure speleothems. Artificial light can raise the cave temperature and disturb bat colonies.
- Disturbance of bat colonies often results in their abandoning the cave altogether, resulting in a loss of nutrient input in the form of bat guano.
- Compaction (by trampling) or liquefaction of floors destroys cave soil flora and fauna, and can cause the ultimate "biological death" of the cave.
- Erosion or disturbance to cave sediments and their contents, e.g. the stairway that was cut through a fossiliferous debris cone in the Sterkfontein Tourist Cave.
- Physical destruction of speleothems and mineral crystal growths by collectors, cavers, tourists, scientists and unauthorised persons.
- Disturbance and displacement of troglodytic and troglophilic fauna, e.g. porcupines, owls, bats.
- Introduction of alien organisms, e.g. algal and fungal spores, bacteria.
- Introduction of alien materials such as metals, concrete, climbing aids, monitoring equipment, cables, lighting.
- Introduction of pollutants, e.g. paper, plastic, foil, lint from clothing, etc.
- Raised CO_2 and temperature levels.
- Raised dust levels, which spoils speleothems.

- Surface impacts, such as compaction, erosion, abrasion, sediment disturbance.
- Outside the cave, altered patterns of drainage by the creation of paths and walkways.
- Vandalism, graffiti.

Carbide Lighting Carbide lighting is extremely polluting, not only from used carbide dumping within caves, but more particularly from the **soot** which such lighting generates. This wafts through the cave air, and carried by natural draughts - sometimes over hundreds of metres - is deposited on every surface: in the long term, everything becomes black or grey. Soot production from decades of carbide lighting at Sterkfontein has ruined the once sparkling crystal formations in the Name Chamber and permanently sullied all the other speleothems on the tourist route.

4.8.2 The impact of caves on humans

- Dangers to persons utilising caves are both visible and invisible. In addition, there is the ever-present hazard of site instability (see Overall Cultural Heritage Management Plan).
- Visible hazards include uneven substrates, walls and ceilings, vertical drops and tight passages. Sudden claustrophobia can be a problem with some visitors.
- Invisible hazards include the risk of Histoplasmosis, radon emissions and high CO_2 levels.
- Caves are inherently unstable. Instability is usually the result of ongoing geological processes, such as dissolution, decalcification and erosion, and results in unpredictable sudden collapses of roof blocks (in mining jargon, called “coffin lids”), usually along natural bedding planes.
- Site instability can also be exacerbated by activities on the surface, such as excavations, which may create sumps for storm water. Channeling of surface water flow by footpaths and dumped material is also problematic. The use of explosives or pneumatic drills on the surface increases the risk of underground collapse.

Histoplasmosis:

"Cave Disease"

Cave Disease or Histoplasmosis is a debilitating lung disease caused by the inhalation of non-filterable fungal spores. The spores originate from the fruiting bodies of the fungus *Histoplasma capsulatum*, which grow on the thick powdery beds of bat guano deposited on cave floors under bat roosts. Several species of bats are colonial, and roosts can cover many square meters of the cave roof. Tramping on the guano beds raises clouds of spores with each step.

Inhaled spores germinate in the moist humid darkness of the human lungs. Fungal hyphae (fine threads of fungus) grow and can fill the lungs. The hyphae and the toxins they produce cause lung irritation, a persistent cough, and 'flu-like' symptoms. Antibiotics do not help and in fact may even facilitate further growth of the hyphae. Ultimately, the irritation set up in the lungs may cause cyst-like nodules to form, resulting in permanent lung damage and impaired lung function. Smokers and HIV positive persons are at greater risk. There is no known cure for the nodules once developed. The disease can be fatal.

4.8.3 Commercialisation of caves

- The rapid rise in popularity of “adventure tourism” and “adventure sports” has resulted in an increase in the commercial exploitation of caves in the COH WHS.
- Commercial exploitation of caves would appear to be an important cause of cave degradation, through over-use and insensitive, uncontrolled utilisation.
- Commercial operators appear to be unaware of the Caving Code of Conduct and fail to educate users in this matter.
- Reduced local bat populations is one monitorable effect of over-exploitation, and populations of the long-fingered bat, *Miniopterus schrebersii*, are diminishing to a point of concern.
- Operators charge as much as R 250 per person per day, depending on cave quality and level of challenge; and even more if technical access equipment is required. This makes the operation of a caving business a financially attractive option.
- Approximately 11 “unofficial” operators are interfacing with landowners and are operating without controls in the COH.
- Degradation in the form of artificial entrance enlargement to accommodate tourist needs over the past year is causing alarm in the serious caving organisations. Access enlargement causes major alterations in airflow, temperature and dust levels, and impacts strongly on cave ecosystems.

Risk Factors for Developing Fungal Infections, including Histoplasmosis:

1. Therapy that suppresses the immune system • Anticancer drugs (chemotherapy) • Corticosteroids and other immunosuppressant drugs **2. Diseases and Conditions** • AIDS • Kidney failure • Diabetes • Lung disease, such as emphysema • Hodgkin's disease or other lymphomas • Leukemia • Extensive burns

Histoplasmosis and AIDS **(source: Merck Manual of Medical information: Fungal Infections)** • There are three forms of Histoplasmosis: the **acute form** (seldom fatal), the **progressive disseminated form**, and the **chronic cavitary** form. • The **progressive disseminated form** doesn't normally affect healthy adults. • This form normally occurs in infants and in people who have an impaired immune system, such as those with AIDS. • Symptoms may worsen either very slowly or extremely rapidly • These include enlargement of the liver, spleen and lymph nodes, ulcers in the mouth and intestines, and in rare cases, damage to the adrenal glands, causing Addison's disease. • Without treatment, the **progressive disseminated form** of Histoplasmosis is fatal in 90% of people. • Even with treatment, death may occur rapidly in people with AIDS. • It is essential to post special risk warnings at infected caves, and for tour guides to specially draw attention to the risks. • Researchers and students should be made aware of the special risk factors for developing fungal infections, and in particular the exacerbated risks for AIDS and HIV positive persons.

Radon • Radon is an inert radioactive gas that occurs in limestone (dolomitic) caves • Radon is one of the products of the radioactive decay of Uranium, an element which is usually present in minute amounts in limestone or the adjacent rocks. • Being a gas, radon seeps from the rocks into the surrounding air. • Normally, air currents disperse radon to relatively low concentrations, but in a confined space such as a cave, the concentration can build up. • This is particularly hazardous where ventilation turnover is slow, such as in the stuffy sack-type caves common in the COH WHS. • Radon and its decay products (which themselves are radioactive) present in the air can be breathed into the lungs, where radioactive decay may occur, thus causing the person to receive a dose of radiation. Prolonged exposure may lead to lung cancer. • This has implications for those who work in caves, such as tour guides or cave monitors. • The radon levels in our caves have not yet been determined. • The legal position vis-à-vis land owners and business owners and their liabilities and responsibilities is also unclear. • The legal necessity of posting warnings at those caves where paying visitors are accepted should be clarified.

4.9 Urbanisation

- Encroaching urbanisation means more boreholes and increased groundwater abstraction.
- Encroaching urbanisation increases the risk of groundwater pollution as well as the pollution of local waterways. The conspicuous development along the southern boundary of Bolts' Farm is unfortunate.

5 RECOMMENDATIONS

5.1 General guidelines for cave and Karst protection

The following guidelines apply to Karst and cave areas in general:-

- Effective planning for Karst regions and caves demands a full appreciation of all their economic, scientific and human values, within the local cultural, scientific and political context.

- The integrity of any Karst system depends upon an interactive relationship between land, water and air. Any interference with this relationship is likely to have undesirable impacts, and should be subjected to thorough environmental assessment.
- Land managers should identify the total catchment area of any Karst lands, and be sensitive to the potential impact of any activities within the catchment, even if not located on the Karst itself.
- Destructive actions in Karst, such as quarrying or dam construction, should be located so as to minimise conflict with other resource or intrinsic values.
- Pollution of groundwater poses special problems in Karst and should always be minimised and monitored. This monitoring should be event-based rather than merely at regular intervals, as it is during storms and floods that most pollutants are transported through the Karst system.
- While recognising the non-renewable nature of many Karst features, particularly within caves, good management demands that damaged features be restored as far as is practicable.
- The development of caves for tourism purposes demands careful planning, including consideration of sustainability. Where appropriate, restoration of damaged caves should be undertaken, rather than opening new caves for tourism.
- The Gauteng Government should ensure that a representative selection of Karst sites is declared as protected areas under provincial legislation.
- Priority in protection should be given to areas or sites having high natural, social or cultural value, those possessing a wide range of values within the one site, those which have suffered minimal environmental degradation; and/or of a type not already represented in protected areas elsewhere in the country.
- Protected area should include as much as possible of the total catchment area of the Karst - although this is not possible in Gauteng.
- Where such coverage is not possible, environmental controls or total catchment management agreements under planning, water management or other legislation should be used to safeguard the quantity and quality of water inputs to the Karst system.
- Public authorities should identify Karst areas not included within protected areas and give consideration to safeguarding the value of these areas by such means as planning controls, programs of public education, heritage agreements or covenants.
- Management agencies should seek to develop their expertise and capacity for Karst management.
- Managers of Karst areas and specific cave sites should recognise that these landscapes are complex three-dimensional integrated natural systems comprising rock, water, soil, vegetation and atmospheric elements.
- Management in Karst and caves should aim to maintain natural flows and cycles of air and water through the landscape in balance with prevailing climatic and biotic regimes.
- Managers should recognise that in Karst, surface actions may be sooner or later translated into impacts directly underground or further downstream.
- Pre-eminent amongst Karst processes is the cascade of carbon dioxide from low levels in the external atmosphere through greatly enhanced levels in the soil atmosphere to reduced levels in cave passages. Elevated soil carbon dioxide levels depend on plant root respiration, microbial activity and a healthy soil invertebrate

fauna. This cascade must be maintained for the effective operation of Karst solution processes.

- The mechanism by which this is achieved is the interchange of air and water between surface and underground environments. Hence the management of quality and quantity of both air and water is the keystone of effective management at regional, local and site specific scales. Development on the surface must take into account the infiltration pathways of water.
- Catchment boundaries commonly extend beyond the limits of the rock units in which the Karst has formed. The whole Karst drainage network should be defined using planned water tracing experiments and cave mapping. It should be recognized that the boundary of these extended catchments can fluctuate dramatically according to weather conditions, and that relict cave passages can be reactivated following heavy rain.
- More than in any other landscape, a total catchment management regime must be adopted in Karst areas. Activities undertaken at specific sites may have wider ramifications in the catchment due to the ease of transfer of materials in Karst.
- Soil management must aim to minimise erosive loss and alteration of soil properties such as aeration, aggregate stability, organic matter content and a healthy soil biota.
- A stable natural vegetation cover should be maintained as this is pivotal to the prevention of erosion and maintenance of critical soil properties.
- Establishment and maintenance of Karst protected areas can contribute to the protection of both the quality and quantity of groundwater resources for human use. Catchment protection is necessary both on the Karst and on contributing non-Karst areas. Activities within caves may have detrimental effects on regional groundwater quality.
- Management should aim to maintain the natural transfer rates and quality of fluids, including gases, through the integrated network of cracks, fissures and caves in the Karst. The nature of materials introduced must be carefully considered to avoid adverse impacts on air and water quality.
- The extraction of rocks, soil, vegetation and water will clearly interrupt the processes that produce and maintain karst, and therefore such uses must be carefully planned and executed to minimise environmental impact. Even the apparently minor activity of removing limestone pavement or other karren for ornamental decoration of gardens or buildings has a drastic impact and should be subject to the same controls as any major extractive industry.
- Imposed fire regimes on karst should, as far as is practicable, mimic those occurring naturally.
- While it is desirable that people should be able to visit and appreciate karst features such as caves, the significance and vulnerability of many such features means that great care must be taken to minimise damage, particularly when cumulative over time. Management planning should recognise this fact and management controls should seek to match the visitor population to the nature of the resource.
- International, regional and national organisations concerned with aspects of karst protection and management should recognise the importance of international co-operation and do what they can to disseminate and share expertise.
- The documentation of cave and karst protection/management policies should be encouraged, and such policies made widely available to other management authorities.
- Data bases should be prepared listing cave and karst areas included within protected areas, but also identifying major unprotected areas which deserve recognition and

protection. Karst values of existing and potential World Heritage sites should be similarly recorded.

5.2 Specific Recommendations for Cave and Karst protection in the Cradle of Humankind World Heritage Site

5.2.1 Hydrology

The following actions are recommended to monitor and protect water quality:-

- A comprehensive geohydrological audit of the COH WHS, which includes identification of water compartments, should be conducted. This should include an inventory of boreholes, and a database of groundwater abstraction.
- Establish the impacts of mine dewatering south-west of the COH WHS.
- Monitor groundwater abstraction by strategically placed borehole monitors.
- Investigate the Percy Stewart outfall sewer and all other similar installations in the COH WHS, and assess their impacts within the catchment and recharge area of the Blaauwbank Spruit.
- Upgrade the Percy Stewart works and seek alternatives to discharging into the Blaauwbank Spruit. Should this not be feasible, establish as nitrate-absorbing wetland prior to the discharge point, e.g. located in the fields below the works. A hydroponic type vegetable production scheme could be investigated. This might be of interest to local communities.
- The degraded wetland on the Blaauwbank, particularly north of Swartkrans, should be rehabilitated. This degradation is primarily a feature of the last decade or two.
- Water quality throughout the COH WHS should be monitored in such a way that offending polluters can easily be identified and controlled.
- Because of the serious risk of groundwater pollution, special precautions need to be taken when installing sanitation. This applies just as much to individual property owners as it does to new large-scale developments. It may be necessary to pass special by-laws applicable to the COH WHS, or to all dolomitic areas, to ensure that appropriate sanitation is installed.

5.2.2 Pollution

- Even if the source of pollution is located far outside the Karst area itself it can have devastating impacts. For this reason, potential pollution risks from industrial sites, fuel storage sites, waste dumps, domestic and farming residues, as well as from sewerage, will have to be identified and monitored throughout the COH WHS.

5.2.3 Farming, feedlots and fish

- Farmers should be discouraged from ploughing up wetlands. Enforcement of environmental legislation could help in this regard.
- Siltation of waterways downstream of degraded wetlands should be monitored and appropriate action taken.
- Water quality downstream of the Blaauwbank Valley Trout Farm should be monitored for water quality and fish pathogens.

5.2.4 Human utilisation of caves

- The impacts of cave visitation by humans (outlined above) present a complex conservation problem. The extensive and growing volume of publications on this subject is testimony to the complexities of the field.

- Regardless of the reasons for cave visitation, the same fragile cave ecosystem is at risk, and all cave users must comply with a set of conservation guidelines, such as those proposed by the IUCN. The enforcement of the code would only be possible if a permitting system for cave visitation is set up.

5.2.5 Recommendations concerning visitor numbers and frequency

- Visitor numbers should be kept to a minimum, based on cave type and size, remembering that single-entranced sack-type caves with a slow ventilation turnover have a very slow recovery rate. (See Appendix II for method to calculate carrying capacity).
- Cave "nano bots" (bacteria, algae, fungi, insects etc.), are extremely sensitive and both require and produce an active, aerated, loose cave floor environment, which hosts many micro-ecosystems and food chains. In a "wild" cave with a low visitation frequency, cave floor compaction due to trampling may rehabilitate within two to three months. On the other hand, frequently visited caves become progressively compacted into dimpled hard "pavements", which do not rehabilitate at all, and the micro-organisms and processes of the substrate are destroyed.
- Over-used caves eventually become biologically and geologically dead, and their tourist value becomes progressively diminished.
- Impacts of visitation increase with distance from the cave entrance, the further and deeper within the cave that disturbance occurs, the longer it takes for the environment to recover.
- In those caves which are designated for use as tourist caves, the impact of compaction due to trampling can be minimized by installing raised walkways and loosening previously compacted areas.
- A formula for calculating visitation frequency based on cave volume, cave form and type, maximum allowable temperature, carbon dioxide levels, humidity and visitor numbers, is included in Appendix II. This should be used to calculate maximum visitor capacity, which will be different for every cave.
- Monitoring visits need to be accommodated in the calculation of visitation frequency.
- The compaction level of floors can be used as one of the monitoring indicators for the eco-stability of a cave environment, as can the presence of bat colonies or "fresh" bat guano (taking seasonality into account).

5.2.6 Recommendations regarding caving equipment and personal attire

- Textiles that limit the shedding of lint ("pill") should be considered.
- Portable Lighting: Only battery driven torches and lamps with sealed batteries should be used. Solid and liquid fuel lamps e.g. carbide, paraffin and gas all produce hydrocarbons, which are environmentally detrimental.
- AC primary mains are not desirable because they generate excessive luminous heat.
- It should be borne in mind that inductive fields develop around feeder cables causing galvanic and electromagnetic force effects along the length of the cable during "light on" time.
- Demarcation of sensitive areas should be done with non-degradable washed (post manufacture) PVC plastic barrier tape.
- Unstable screed slopes or debris cones and areas of subsidence should be retained with heavy duty shade netting, not wooden supports (wood rots releasing CO_2).
- All personal equipment should be clean and contain no soil or dust from other caves (NB boots and shoes) to avoid cross-contamination (Histoplasmosis spores,

bacteria) from one cave to another.

- All technical access apparatus should be removed after each visit.

5.2.7 Guidelines regarding the erection of cave gates

- The gating of caves requires a number of special considerations. The goal is to allow all cave-dwelling creatures continued undisturbed access, while ensuring that unwanted intruders are kept out.
- The gate must provide for free flow of air and an adequate flight path for birds and bats.
- Gates should be kept as simple as possible.
- Due to the corrosive propensity of mild steel and the availability of modern environmentally friendly eco-stabile metals, 316/304-grade stainless steel is recommended.
- This should be set in a moulded concrete anchor network, allowing access to cave fauna.
- Anchor braces to be made of concrete away from the cave. All concrete components should be curved, moulded and toned, and not boxed.
- Trees growing at cave entrances should not be used as anchors, nor should they be felled or incorporated into the gating mechanism in any way.
- The gate locking mechanism should be recessed and hard to access, to prevent forced removal of the lock. All metal structures to be made from stainless steel and these should be prefabricated (made to measure) away from the cave.
- Careful thought and planning on the type of closure and gate design is required. Cave gates always need to be hand made and the design of each is site specific.
- Note that before a gate can be installed, a permit from DACEL (and possibly SAHRA as well) will be necessary. It is unlikely that landowners will be aware of either this requirement, or of gate-building specifications.

5.2.8 Engineering and technical guidelines in Karst areas

- If caves are to be used as tourist venues, infrastructure such as roads and car parks should be planned with care, and not sited over voids.
- Access roads and car parks should be paved to minimise dust, which often enters the cave, as happens with the unpaved car park at Wonder Cave.
- Care should be taken that footpaths and other landscaping details or infrastructure such as steps do not interfere with, or negatively impact on, the flow of water into the cave. Pooling of water should be avoided.
- Mild steel and wooden infrastructure should not be used in dolomitic caves because of the CO_2 released.
- Pit-latrines should not be allowed on dolomitic areas, because of ground-water pollution.
- Geophysical and drilling investigations must be completed prior to new building to minimise risk of collapse into sinkholes.
- The rugged “tank trap” terrain often encountered in dolomitic areas makes the concealment of pipes etc difficult and expensive. Burying such infrastructure necessitates blasting and environmental damage. This should be borne in mind during the planning stage of developments. Raised pipelines are unsightly, e.g. Sterkfontein.

6 SPECIFIC MANAGEMENT INTERVENTIONS REQUIRED

6.1 The need for a cave register (inventory) and database

Before the heritage significance or heritage potential of dolomitic caves can be conserved, or any permitting system effectively implemented, the management authority/ies would have to know:

1. Where the dolomitic caves are situated i.e. an inventory of caves, their names (if any) and locations.
2. What the status of each cave is, i.e. whether it is pristine or near pristine, (Code 1, See below), a “limited access” high-quality cave (Code 2) a “high intensity access” cave such as a show cave, like Wonder Cave (Code 3), or a “forfeit cave” like Sterkfontein, which in addition to the damage caused by over-use, has been mutilated by speleothem mining and harvesting (Code 4).
3. How many visitors there are, and visitation patterns i.e. a visitor database.

Caving organizations in South Africa, either CROSA (Cave Research Organization of South Africa) SASA (Speleological Association of South Africa), in the absence of any higher body of effective control or conservation have hitherto not been prepared to divulge information concerning the whereabouts of caves. Such disclosure contravenes their conservation ethic and/ or constitutional policy. Non-disclosure has been a “management strategy”.

Non-disclosure and mutual secrecy has also been the result of an unfortunate and long-standing feud between the two organizations. Because of this secrecy, most of the known caves bear up to four different names and have been “discovered” several times in the last 100 years. This adds a confusing element to the construction of a database. However, between CROSA and SASA, there is a locality record of those caves known to them, their names, approximate sizes and some are documented in the form of a cave survey. Some caves are known only to individuals.

It appears that shortly this tactic of non-disclosure will no longer be effective, as satellite-based magnetometry enables underground caves to be detected from above ground. Such information will soon become available on the Internet. Free access to information of this type could pose management problems and necessitate a variety of on-the-ground measures. It might be possible to resolve the differences between the two rival caving organizations by enlisting their help and inviting representatives from each to serve on the policy making body of the Management Authority.

6.2 Protection and security: control of commercial operators, caving organizations, researchers, mineral collectors and casual explorers

As things stand, there is inadequate control of all these users of the subterranean environment. Commercial caving has been identified as perhaps the greatest threat to subterranean ecology in the COH WHS. The loss of bat populations from caves targeted by commercial operators bears testimony to their ongoing degradation. Recommendations are as follows:-

1. Commercial exploitation of caves should be subject to a permit. Permit issue should be subject to a set of Operations Guidelines, an Environmental Code and a User

Code of Conduct that should be issued with the permit and adhered to at all times. This would include limitation of visitor numbers and visitation frequency. Permits and licenses should be subject to satisfactory performance.

- Ethical behavior and quality of visitor experience should be monitored by site monitors.
- A permitting system could generate funding for cave protection and monitoring, and might enable those responsible for causing damage to be held responsible. Landowners with caves should also be required to apply for permits if they embark upon commercial operations.
- Issues such as site safety and public liability need to be addressed.
- There is no formal Cave Rescue organization apart from expertise within the two caving organizations. A Cave Rescue could take several weeks, putting enormous strain on local emergency services - for example, the failed rescue of a diver at Sterkfontein. Who should bear the costs of such rescue operations?
- Caving organizations and researchers are not blameless in their abuse of caves.
- The risk of damage by mineral collectors and casual explorers is difficult if not impossible to control. On-the-ground measures will have to be put in place (e.g. Gating, ranger patrols on weekends) at pristine caves worthy of preservation.

6.3 Scientist and Sampling: The need for a revised system of permitting

- Until recently, scientists have had a very cavalier attitude towards taking samples from caves, and there is recent evidence of intrusive behavior on the part of scientists. Information yield is not a satisfactory excuse for unnecessarily destructive sampling procedures.
- A sampling permit is required form SAHRA for the removal of any samples of travertine, breccias or cave sediments. Up to the present time, such permits have been issued subject to the submission of a satisfactory and approved research proposal. There is no follow through enquiry as to the nature of the sampling procedure, or the type of sampling equipment employed, or an inspection of the "sample" and sample site prior to and after sampling by a SAHRA monitor.
- Technically when speleothems or breccias are sampled, the "control half" or witness portion of the sample should be left in place or deposited in a suitable institution. However, this is seldom effectively applied. This has resulted in destructive mistakes, such as the removal of stalactites and stalagmites far too heavy for extrication from the cave. These have then been abandoned on the cave floor, muddied from manhandling.
- Such speleothem sampling and removal should be conducted in the most unobtrusive manner possible, i.e. sample from a remote area of the cave.
- The sample and sample site should be inspected and approved by SAHRA.
- A Code of Conduct for sample taking, whether of geological, sedimentological or biological material, or water samples should be drawn up and adhered to, in order to prevent unnecessary damage to caves and their contents.

7 THE REHABILITATION OF DAMAGED CAVES

- Foreign material removal: remove all metal, wood, plastic, dumped spent carbide, wax, batteries and all other litter from cave.
- All metal and wooden cave infrastructure to be replaced with eco-friendly material.
- Substrate compaction to be rehabilitated by gentle turning of walkways only, not the entire cave floor.
- Artificial entrance enlargement should be rehabilitated to restore original configuration.
- Entrance size controls ventilation turnover, which in turn impacts on temperature and relative humidity, which influences bat roosting behavior and reproduction. Torpor in bats is temperature and relative humidity dependent.
- Reconstruction of broken speleothems is controversial. If deemed advisable, affixing with epoxy glues is an acceptable technique. Some cave managers advocate leaving broken speleothems as an example of what not to do.
- Dirty speleothems can be cleaned with high-pressure hoses, but water (drawn from the cave preferably) and electricity is needed.
- Algal blooms on speleothems may be cleaned in the same way and lighting adjusted.
- Artificial enlargement of cave passages to be remedied, as this affects cave "breathing".
- Restriction of access to the cave is part of the rehabilitation process.
- Gates can be installed to facilitate access control (see Section 5.2.7).

8 MONITORING CAVES: MONITORING GUIDELINES

- Check for presence of foreign material as mentioned above.
- Check abrasion levels - access equipment chafes, floor and wall abrasion due to excessive traffic, smoothing of speleothems.
- Check eutrophication levels.
- Monitor CO_2 levels at intervals throughout the year to establish a baseline. Should changes to CO_2 level be greater than 0.24 from an atmospheric CO_2 level of 0.03, the cave should be closed or not accessed by tourists. Raised CO_2 levels are hazardous to tourists and caves alike, and may cause speleothem degeneration, as has happened in the Cango Caves.
- Monitor temperature: this varies from 17 to 19 degrees centigrade annually in Gauteng caves. Visitor numbers and inappropriate lighting raises temperature.
- Relative humidity (RH) - expensive to monitor. RH is a key factor in bat biology and speleothem formation.
- Bat monitoring. Populations of bats are declining all over the world, and should be considered a priority from a bio-diversity and pest management point of view. Roost locations for the different bat species should be identified and monitored.
- Known recent bat roost sites, e.g. Gladysvale, should be upgraded and rehabilitated as soon as possible.
- A National Bat Biology Programme should be instigated. Many species of bats are migratory, and are not confined to the Gauteng Province.
- Monitor cave groundwater for *E. coli* .
- Check CO_2 levels, RH, temperature and Radon emission levels.
- Establish whether or not Histoplasmosis is present.

9 FURTHER RECOMMENDATIONS

- Education programme concerning the subterranean environment and its biota as a fragile eco-system for schools.
- Education concerning the subterranean environment as a cultural heritage resource.
- Educate landowners and farmers about caves and their value.
- Prepare a Code of Conduct booklet for farmers and landowners.
- Promote further research into cave mycology and numerous other aspects of cave biology and geology.
- Increase public awareness about the hazard of Histoplasmosis in combination with AIDS and other medical conditions (refer to text boxes on Histoplasmosis). Note that this disease is rarely fatal in healthy adults.

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APPENDIX I: A SYSTEM OF RATING CAVE QUALITY: CODES I TO IV

Once the whereabouts of subterranean cavern resources has been recorded in an Inventory, together with an associated database, each cave should be assessed for quality, significance and proposed use. Each category of cave will require a different management strategy.

Code I: Undisturbed, pristine cave - preferably no used, off-limits conservation area (Target: 94% total suite of caves).

Code II: Limited Access Cave - for use by speleologists, scientists (Target 94% of total suite of caves, together with Code I)

Code III: High Intensity Use - for use as show caves (tourists, general public), or multi-purpose caves (general use). (5% of suite).

Code IV: Forfeit Caves - disturbed caves of little scientific, educational or tourism use - casual untrained public groups (1% of suite)

APPENDIX II: EXTRACT ON DETERMINATION OF CARRYING CAPACITY IN CAVES FROM GAMBLE'S THESIS

Extract from: Gamble, F.M. 1981. The Management of Karst Cave Ecosystems in the Transvaal, Ph.D. Thesis, Department of Geology, University of Natal.

APPENDIX III GENERAL GUIDELINES FOR THE PROTECTION OF KARST LANDSCAPES AND CAVES

- Effective planning for Karst regions and caves demands a full appreciation of all their economic, scientific and human values, within the local cultural, scientific and political context.
- The integrity of any Karst system depends upon an interactive relationship between land, water and air. Any interference with this relationship is likely to have undesirable impacts, and should be subjected to thorough environmental assessment.
- Land managers should identify the total catchment area of any Karst lands, and be sensitive to the potential impact of any activities within the catchment, even if not located on the Karst itself.
- Destructive actions in Karst, such as quarrying or dam construction, should be located so as to minimise conflict with other resource or intrinsic values.
- Pollution of groundwater poses special problems in Karst and should always be minimised and monitored. This monitoring should be event-based rather than at merely regular intervals, as it is during storms and floods that most pollutants are transported through the Karst system.
- All other human uses of Karst areas should be planned to minimise undesirable impacts, and monitored in order to provide information for future decision-making.
- While recognising the non-renewable nature of many Karst features, particularly within caves, good management demands that damaged features be restored as far as is practicable.
- The development of caves for tourism purposes demands careful planning, including consideration of sustainability. Where appropriate, restoration of damaged caves should be undertaken, rather than opening new caves for tourism.
- The Gauteng Governments should ensure that a representative selection of Karst sites is declared as protected areas under legislation which provides secure tenure and active management.
- Priority in protection should be given to areas or sites having high natural, social or cultural value; possessing a wide range of values within the one site; which have suffered minimal environmental degradation; and/or of a type not already represented in the protected areas elsewhere in the country.
- Where possible, a protected area should include the total catchment area of the Karst - not possible in Gauteng.
- Where such coverage is not possible, environmental controls or total catchment management agreements under planning, water management or other legislation should be used to safeguard the quantity and quality of water inputs to the Karst system.
- Public authorities should identify Karst areas not included within protected areas and give consideration to safeguarding the values of these areas by such means as planning controls, programs of public education, heritage agreements or covenants.
- Management agencies should seek to develop their expertise and capacity for Karst management.
- Managers of Karst areas and specific cave sites should recognise that these landscapes are complex three-dimensional integrated natural systems comprised of rock, water, soil, vegetation and atmosphere elements.

- Management in Karst and caves should aim to maintain natural flows and cycles of air and water through the landscape in balance with prevailing climatic and biotic regimes.
- Managers should recognise that in Karst, surface actions may be sooner or later translated into impacts directly underground or further downstream.
- Pre-eminent amongst Karst processes is the cascade of carbon dioxide from low levels in the external atmosphere through greatly enhanced levels in the soil atmosphere to reduced levels in cave passages. Elevated soil carbon dioxide levels depend on plant root respiration, microbial activity and a healthy soil invertebrate fauna. This cascade must be maintained for the effective operation of Karst solution processes.
- The mechanism by which this is achieved is the interchange of air and water between surface and underground environments. Hence the management of quality and quantity of both air and water is the keystone of effective management at regional, local and site specific scales. Development on the surface must take into account the infiltration pathways of water.
- Catchment boundaries commonly extend beyond the limits of the rock units in which the Karst has formed. The whole Karst drainage network should be defined using planned water tracing experiments and cave mapping. It should be recognized that the boundary of these extended catchments can fluctuate dramatically according to weather conditions, and that relict cave passages can be reactivated following heavy rain.
- More than in any other landscape, a total catchment management regime must be adopted in Karst areas. Activities undertaken at specific sites may have wider ramifications in the catchment due to the ease of transfer of materials in Karst.
- Soil management must aim to minimise erosive loss and alteration of soil properties such as aeration, aggregate stability, organic matter content and a healthy soil biota.
- A stable natural vegetation cover should be maintained as this is pivotal to the prevention of erosion and maintenance of critical soil properties.
- Establishment and maintenance of Karst protected areas can contribute to the protection of both the quality and quantity of groundwater resources for human use. Catchment protection is necessary both on the Karst and on contributing non-Karst areas. Activities within caves may have detrimental effects on regional groundwater quality.
- Management should aim to maintain the natural transfer rates and quality of fluids, including gases, through the integrated network of cracks, fissures and caves in the Karst. The nature of materials introduced must be carefully considered to avoid adverse impacts on air and water quality.
- The extraction of rocks, soil, vegetation and water will clearly interrupt the processes that produce and maintain karst, and therefore such uses must be carefully planned and executed to minimise environmental impact. Even the apparently minor activity of removing limestone pavement or other karren for ornamental decoration of gardens or buildings has a drastic impact and should be subject to the same controls as any major extractive industry.
- Imposed fire regimes on karst should, as far as is practicable, mimic those occurring naturally.
- While it is desirable that people should be able to visit and appreciate karst features such as caves, the significance and vulnerability of many such features means that great care must be taken to minimise damage, particularly when cumulative over time. Management planning should recognise this fact and management controls

should seek to match the visitor population to the nature of the resource.

- International, regional and national organisations concerned with aspects of karst protection and management should recognise the importance of international co-operation and do what they can to disseminate and share expertise.
- The documentation of cave and karst protection/management policies should be encouraged, and such policies made widely available to other management authorities.
- Data bases should be prepared listing cave and karst areas included within protected areas, but also identifying major unprotected areas which deserve recognition. Karst values of existing and potential World Heritage sites should be similarly recorded.